



# **National Survey and Review of Maternal Near Miss in Oman**

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**By**

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# Abstract

## National Survey and Review of Maternal Near Miss in Oman

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**Background:** Review of the care provided to women who nearly died but survived complications occurring during pregnancy, childbirth, or the postnatal period, known as maternal near miss (MNM). It is one of the recommended approaches to improve the quality of care (QoC) especially in settings with few maternal deaths. Oman has a well-established maternal deaths surveillance system, but there has not been a significant decline in the maternal mortality ratio, and the majority of maternal deaths are considered preventable. In addition, the burden of severe maternal morbidity is unknown. This study explores the potential of MNM review to improve quality of care in Oman. The objectives are to determine the incidence, underlying causes of, and factors associated with MNM in Oman, to assess QoC and make recommendations for its improvement.

**Method:** Existing WHO guidelines and criteria were reviewed, and a systematic review of the literature was conducted to establish criteria for the identification of MNM in Oman. A national survey with in-depth review of MNM cases was implemented. MNM cases were identified from 23 hospitals across all 11 governorates, capturing more than 90% of total deliveries in the country. Between October 2016 and September 2017 all cases fulfilling the MNM criteria were reviewed at the hospital and regional levels by trained reviewers. 50% of cases were reviewed additionally by the National Maternal Mortality Review Committee and a panel of international experts. The level of agreement between various levels of reviewers was determined using Cohen's kappa coefficient.

**Results:** During the one-year period of data collection a total of 25 maternal deaths and 312 MNM cases were reported, given an MNM incidence of 4.0 per 1000 women giving birth (deliveries), and a ratio of MNM: maternal mortality of 10.3:1. Hypertensive disorders (44%), obstetric haemorrhage (23%), and non-obstetric complications (18%) were the most common underlying causes of MNM. Previous caesarean sections (20.0%), medical disorders (20.0%), and grand-multiparity (20.0%) were the main contributory conditions to MNM. Overall there was good care given (43.6%). In up to 36.5% of cases improved care could have made a difference to the outcome. The most commonly identified associated factors were related to the healthcare team providing care (50.0%), in particular inappropriate management (28.2%) and failure to initially recognise the seriousness of the condition (25.6%). Factors related to the women themselves included non-adherence to prescribed treatment, delay in seeking care was associated with around one third of MNM events. Factors related to organisation of care were recorded in about a quarter of all MNM events with non-availability or outdated policy and guidelines identified as the most common identified factors.

**Conclusion:** The study used a participatory process to develop criteria for identify MNM and a system for reviewing these. It demonstrated it is feasible to complement maternal deaths review with MNM review. The most common causes of MNM are preventable, and the majority of factors associated with MNM are within the scope of health system resources. Using participatory approach that involved international experts, Omani health workers and managers, an action plan for improvement of QoC in Oman was developed.

## **Dedication**

To my father Taiseer, who would be so proud of this success.

To my beloved mother Saleema: without your boundless love and encouragement I would never become the person that I am now.

To my supportive husband Abdulrahman: without your unwavering support, patience, motivation, and understanding, I could have never been able to complete this journey and been successful in my career.

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## Abbreviations

AFE	Amniotic fluid embolism
ANC	Antenatal care
ANOVA	Analysis of variance
CEMNM	Confidential Enquiry into MNM
CFR	Case Fatality Rate
CI	Confidence interval
CPR	Cardiopulmonary resuscitation
C-section	Caesarean Section
CSS	Cross-sectional study
DoHI&S	Department of Health Information and Statistics (MoH)
GA	Gestational age
GIT	Gastrointestinal tract
HDU	High dependency unit
HIC	High-income countries
ICD	International Classification of Diseases
ICU	Intensive care unit
LMIC	Low-middle income countries
LSTM	Liverpool School of Tropical Medicine
MD	Maternal death
MEWS	Modified Early Warning System
MI	Mortality Index
MDR	Maternal death review
MDRS	Maternal Death Surveillance and Response
MENA	Middle East and North Africa
MMR	Maternal mortality ratio
MNM	Maternal near-miss
MNMR	Maternal near-miss ratio
MMR	Maternal mortality ratio
MoH	Ministry of Health (Oman)
NHS	National Health Service (UK)
PE	Pulmonary embolism
PHC	Primary health care
PI	Principle investigator
PIH	Pregnancy induced hypertension

PLTC	Potentially life-threatening condition
PNC	Postnatal care
PPH	Postpartum haemorrhage
PROM	Prelabour (premature) rupture of membranes
QoC	Quality of care
RCA	Root cause analysis
SB	Stillbirth
SCASMM	Scottish Confidential Audit of Severe Maternal Morbidity
SD	Standard deviation
SMO	Severe maternal outcome
SOFA	Sequential Organ Failure Assessment
UAE	United Arab Emirates
UK	United Kingdom
UKOSS	UK Obstetrics Surveillance System
USA	United States of America
WHO	World Health Organisation

## Operational Definitions

Term	Definition
Associated factor	A non-medical factor that contributes to the severe maternal outcome such as socioeconomic status of the woman and accessibility and the health facility QoC
Contributory condition	A medical condition that may have contributed or be associated with (but which did not directly cause) MNM or maternal death
ICD-MM	The application of International Classification of Diseases and Related Health Problems (ICD-10) to deaths during pregnancy, labour, and puerperium
Maternal near-miss	“A woman who nearly died but survived a complication that occurred during pregnancy, childbirth or within 42 days of termination of pregnancy” (WHO, 2011)
Maternal death	“Death of a woman while pregnant or within 42 days of termination of pregnancy or its management, but not from accidental or incidental causes” (WHO, 2011)
Maternal condition	Obstetric and medical conditions of mothers that could have contributed to or aggravated severe complications
Potentially life-threatening conditions	“Clinical conditions, including diseases that can threaten a woman’s life during pregnancy and labour and after termination of pregnancy” (WHO, 2011)
SMO	Total number of MNM and maternal deaths

## Declaration

This thesis is the result of my own original work under guidance of my supervisors, except where references are cited. The material contained in this thesis has not been presented nor it is being presented, either wholly or as part, for any other degree or qualification.

Signed:

A handwritten signature in black ink, appearing to be 'Jamila Al Abri', written over a horizontal line.

Date:

11/10/2019

# 1. Introduction

This chapter provides conceptual background about severe maternal morbidity and maternal near-miss (MNM), including the burden of the severe maternal morbidity, interventions targeting reducing maternal mortality and severe morbidity, MNM as a tool to improve quality of care (QoC), and the evolution and uses of MNM. The definition and criteria of MNM are presented along with description with the World Health Organisation approach.

The second part of the chapter provides background information about Oman, including demographic features, health system, maternity services, and the Maternal Death Surveillance System.

The last part of the chapter presents the rationale of the study, and its aim and objectives. It also outlines the thesis structure.

## 1.1. Burden of maternal mortality and morbidity

Despite the global commitment to reduce maternal mortality since the 1990s in the era of the Millennium Development Goals and Sustainable Development Goals, maternal mortality is still unacceptably high, and every day about 830 women die from complications related to pregnancy and childbirth (World Health Organisation [WHO], 2018). There is slow progress toward achieving the target of a maternal mortality ratio (MMR) of less than 70 per 100,000 live births by 2030 (WHO, 2019). Nearly 75% of deaths are due to preventable causes, including severe haemorrhage, pre-eclampsia/ eclampsia, infection, complications during delivery, and unsafe abortions (Say et al., 2014). Moreover, maternal death is considered only the tip of the iceberg. Ashford (2002) argued that for every maternal death, at least another 30 women suffer morbidity related to pregnancy and childbirth.

In fact, the true burden of maternal morbidity is unknown due to the wide variation of conditions and complications that cause maternal morbidity, from common non-life-threatening disorders to severe, life-threatening ones (Koblinsky et al., 2012; Firoz et al., 2013) (**Figure 1.1**). Maternal morbidity is defined as “any condition that is attributed to or aggravated by pregnancy and childbirth that has a negative impact on the woman’s wellbeing” (Firoz et al., 2013).

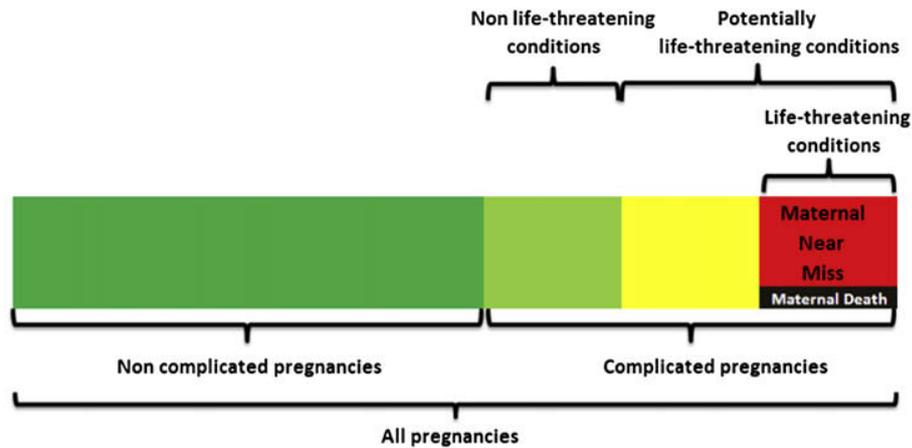


Figure 1.1: Spectrum of maternal morbidity and mortality

Source: Say, Souza and Pattinson (2009)

However, recent research has shown that there remains a significant burden on healthcare systems from maternal morbidity. McCauley et al. (2018) screened 11,454 women from three countries and reported that almost three out of four women suffered ill-health during pregnancy, childbirth, or after delivery. Souza et al. (2013) analysed a multi-country survey on maternal and new-born health in 29 countries by WHO and noted that 7.3% had potentially life-threatening disorders, and 1.0% suffered life-threatening events. Similar to maternal mortality the major causes of severe maternal morbidity are mostly due to preventable obstetric complications.

The impact of maternal morbidity can extend beyond the pregnancy and postpartum periods. Morbidities such as uterine prolapse, perinatal tear, and fistula often result in long-term impacts on woman's social, mental, and physical health (Koblinsky et al., 2012). Moreover, the sequences of events of maternal morbidity can extend to affect the newborn health, as it is well known that neonatal outcomes are linked to maternal health. The three main causes of the 2.9 million annual global neonatal deaths are attributable to infections (0.6 million), intrapartum conditions (0.7 million), and preterm birth complications (1.0 million) (Lawn et al., 2014).

## 1.2. Interventions to reduce maternal mortality and morbidity

By the end of the last century a number of initiatives and strategies were adopted to overcome the burden of maternal ill health. After decades of neglect in the international agenda, the United Nation Agencies launched the Safe Motherhood

Initiative in 1987, which was considered as a promising start to reduce maternal deaths (Jowett, 2000). However, little progress was achieved by this initiative, mainly due to a lack of focus and evidence to support its proposed interventions (Tita et al., 2007). It was also accused of its huge emphasis on primary preventions and antenatal screening (Rosenfield, 1997; Tita et al., 2007; Prata et al., 2010). Thus there have been longstanding calls to invest more in cost-effective interventions that focus on preventing and treating the main causes of birth-related deaths, such as skilled birth attendance and emergency obstetric care, as most obstetric complications can neither be prevented nor predicted (Rosenfield 1997; Tita et al., 2007).

Recently, more emphasis has been placed on improving maternal QoC (van den Broek and Graham, 2009; WHO, 2018), because major causes of both maternal mortality and morbidity could be avoidable in health systems that provide high-quality maternity care. As countries progress through the obstetric transition, more women gain access to health facilities, which can overload unprepared health infrastructure, thus the QoC becomes the main determinant of outcomes (Souza et al., 2014). The access and availability of medical services are fundamentally necessary, but do not in themselves guarantee increased utilisation of these services and are not sufficient alone to reduce maternal mortality and morbidity (Austin et al., 2014). For instance, Gabrysch and Campbell (2009) in their literature review found that perceived QoC is an important determinant of women's health-seeking behaviour.

Furthermore, more evidence has emerged from the *WHO Multi-Country Survey on Maternal and New-born Health* indicating that further reductions in maternal mortality require the overall improvement of maternal QoC, especially in terms of emergency obstetric care (Souza et al., 2013). For example, the Janani Suraksha Yojana conditional cash transfer program in India, which focused on increasing institutional deliveries, resulted in an increase in institutional deliveries, but its impact in improving maternal mortality has been questionable (Lim et al., 2010). Ensuring QoC is a core objective of the WHO Global Strategy for Women's, Children's and Adolescent's Health, 2016-2030 (WHO, 2015a).

### **1.3. Quality of maternal care**

Multiple definitions have been formulated to conceptualise the multiple dimensions of QoC, most of which share core elements (safe, effective, efficient, equitable,

timely and patient centred) (Austin et al., 2014). More specific to maternal services, QoC is defined as:

“The degree to which maternal health services for individuals and populations increase the likelihood of timely and appropriate treatment for the purpose of achieving desired outcomes that are both consistent with current professional knowledge and uphold basic reproductive right” (Hulton, Matthews and Stones, 2000, p.9).

This definition highlights two core components when evaluating the QoC: the quality of the provision of care, and the perceptions of women about the care they have received.

A number of methodologies have been developed to improve QoC, such as the development of guidelines, clinical training, and audits. Guidelines and training are not enough to improve quality if used alone (Raven et al., 2011; Heiby et al., 2014). Audits and feedback are proven by a coherence review to be effective tools to improve professional practice, and as assessment tools for quality improvement (Ivers et al., 2012). Three main categories of audit are used in the area of maternal health; standards-based audit, maternal death audit or review, and “near-miss” audit (Raven, 2011; Lewis, 2014). All three essentially ask the questions:

- What was done well?
- What was not done well?
- How can care be improved in future?

In standards based audits, the practice is compared against explicit standards then the data are used identify the gaps and opportunities for improvement (Tuncalp and Souza, 2014). In maternal death, the term “review” is more appropriate than “audit”, as the latter compares care against guidelines or standards, while in this case such guidelines are expected to be one of the outcomes of the review, which can then subsequently be audited (Lewis, 2014).

Maternal death review is defined as “qualitative, in-depth investigation of the causes of, and circumstances surrounding maternal deaths aiming to find out the medical causes and factors contributed to deaths” (WHO, 2004, p.4). To place more stress on actions taken based on findings from MDR, the concept of “maternal death surveillance and response (MDRS)” was introduced (WHO, 2014). MDR began in the United Kingdom (UK) as a system of confidential inquiries into maternal deaths

in late 1952 (Kurinczuk et al., 2014) After its introduction, its concept was adopted in many settings and contributed to the reduction of maternal deaths in these countries (Pattinson and Hall, 2003; Moodley et al., 2014; Ravichandran and Ravindran, 2014).

## **1.4. Maternal near-miss (MNM)**

### **1.4.1. Evolution of MNM**

Despite its positive contribution, MDR has limitations in providing useful information in setting with low maternal mortality. Today, in many developed countries, maternal death has become a relatively rare event, and thus analysis of maternal deaths might not reflect maternal QoC (Pattinson and Hall, 2003). Thus, audit of severe maternal morbidity known as “near-miss” was introduced as an adjunct to maternal review (Pattinson and Hall, 2003).

Interest in MNM started in the UK, aiming to improve the QoC mainly because of a falling number of maternal deaths. Stones et al (1991) coined the term “near-miss morbidity” to describe “life-threatening morbidity”. They published an article in the *Health Trends* in 1991 in which they reported the result of a retrospective analysis of more than 2,000 maternities. They suggested that enquiry into “near-miss morbidity” might be more useful than confidential enquiry into maternal deaths in identification of deficiency and variation in obstetric management. Following this, a call for expanding confidential enquiry to include MNM increased in the UK for different reasons. For example, there was concern that lessons learned from auditing small unusual events might be forgotten, as they are irrelevant to most maternity units (Drife, 1993; Mantel et al., 1988). Also, the concept of near-miss was also introduced in other specialties to report critical incidents that happened but which did not cause harm (Drife, 1993; Nashef, 2003). Actually, the term “near-miss” was borrowed from the airline industry, although its use in maternal care is obviously different (Pattinson and Hall, 2003). The added values of MNM review or audit compared to maternal death review are:

- Maternal morbidities are more common and share the same characteristic of maternal deaths, thus more information to improve quality can be obtained.
- MNM audit is considered less threatening, so health providers are more open to discuss success and failure (Tuncalp and Souza, 2014).
- A woman who survived can be a source of information of access to care provided (Tuncalp and Souza, 2014; Tuncalp et al.2012a).

### **1.4.2. What is MNM?**

The major epistemological challenge after the introduction of the concept of near-miss has been definition and identification of related cases (Drife, 1993; Mantel et al., 1998; Nashef, 2003). A high threshold for selection of morbidity cases was thought to be useful, otherwise the number of identified cases would overwhelm the system. Additionally, a high threshold makes comparative studies of maternal deaths more relevant.

In the literature, the term “near-miss” is used interchangeably with “severe acute maternal morbidity” to describe a woman who survived severe health complications during pregnancy, intrapartum, or postpartum period (Say, Souza and Pattinson, 2009). For example, Mantel et al. (1998, p.986) defined near-miss as “A very ill woman who would have died had it not been that luck or good care was on her side”. Similarly, Filippi et al. (2000, p.3010) used the term to describe “A severe obstetric complication necessitating an urgent medical interventions in order to prevent the likely death of the mother”, and Prual et al. (2000) used it to refer to “any pregnant or recently delivered woman, in whom immediate survival is threatened and who survives by chance or because of the hospital care she received”.

In 2004, WHO conducted a systematic review on the prevalence of MNM covering the literature from 1997 to 2004 that showed a variation in definitions and criteria used to identify cases (Say, Pattinson and Gulmezoglu, 2004). A working group was established to formulate a definition and identification criteria. They proposed that the term “near-miss” should reflect the concept of “nearly dying but surviving”. Thus, they defined an MNM as an event in which “a woman who nearly died but survived a complication that occurred during pregnancy, childbirth or within 42 days of termination of pregnancy” (Say, Souza and Pattinson, 2009, p.289).

### **1.4.3. Uses of MNM audit**

Following its introduction in the UK, there was growing interest in using MNM concept both in developed and developing countries, for multiple purposes.

- *Evaluating maternal QoC using near-miss*

The concept of MNM was primary developed to evaluate QoC. Over time, a number of literature reviews have shown that there is a growing interest in utilising MNM to evaluate QoC and identify deficiencies in maternity care both in developed and developing countries (Ronsmans et al., 2009; van Roosmalen and Zwart., 2009; Lazzerini at al., 2017). Recently, Lazzerini et al. (2017) synthesised studies from

different regions in the world and provided evidence of MNM review at a facility level reducing MMR and improving QoC in maternal and newborn services.

- *Estimating the met need for life-saving surgery and resources needed*

Data on MNM was used in particular in developing countries to measure the met need for obstetric surgery and for advocating for more resources (Ronsmans, 2009).

- *Estimating the incidence, prevalence, and understanding of the causes and severity of maternal morbidity*

MNM was used extensively to estimate the burden of severe maternal morbidity at the facility and population levels (Say, Pattinson and Gulmezoglu, 2004; Ronsmans, 2009; Roosmalen et al., 2009; Tuncalp et al., 2012a). Tuncalp et al. (2012) in their systematic review found that in less than 10 years the number of studies reporting the prevalence of MNM increased almost threefold. These studies either focused on a single morbidity (Acosta et al., 2014; Fitzpatrick et al., 2012) or addressed multiple ones simultaneously (Almerie et al., 2010; Jabir et al., 2013). Over time, such studies were used to monitor trends of severe morbidities (Roosmalen et al., 2009; Tuncalp et al., 2012a).

- *Exploring risk factors for developing severe maternal outcomes*

Because MNM is more common than maternal deaths, analysis of MNM cases provides valuable information on the risk factors and outcomes of severe maternal morbidities that can be generalised. For instance, in the health systems in the UK and Australia, such data is utilised to inform the development of guidelines, service planning, and for patient information (Halliday et al., 2013; Knight et al., 2014a).

- *Learning from women's personal accounts of near-miss and their experiences of care*

The literature shows that interviewing women who experienced MNM is a powerful tool to identify reasons of delay from seeking medical care and their perception of care they received. Filippi et al. (2009) concluded from their literature review that MNM audits can assist health facility team to reduce women's delays in seeking care. Tunclap et al. (2012b) documented that listening to these women can inform different aspects of health system weakness, which can have positive impacts on informing QoC improvement measures.

- *Documenting the long-term consequences of maternal morbidity*

Information from near-miss cases has been used to document the long-term consequences of maternal morbidity on women and her families. For instance, a

longitudinal follow-up study of women with MNM in Burkina Faso found that they had a high risk of baby loss and disruption in many aspects of their lives (Storeng et al., 2010).

#### 1.4.4. Identification criteria of MNM

The 2004 WHO systematic review (Say, Pattinson and Gulmezoglu, 2004) was repeated again to cover the period from 2004 to 2010 by Tuncalp et al. (2012). Both reviews revealed there are three main categories of criteria used to identify MNM:

- Clinical criteria for a specific disease or condition, such as severe postpartum haemorrhage
- Intervention-based criteria, such as admission to intensive care unit (ICU) or emergency obstetric hysterectomy.
- Organ-dysfunction criteria

All above criteria have advantages and disadvantages, as illustrated in **Table 1.1**.

*Table 1.1 Categories for identification criteria for MNM*

Criteria	Concept	Advantages	Disadvantages
Clinical criteria related to a specific disease	Starting with specific disease, then morbidity is defined by identification of its complications	Easy to interpret Can used in retrospective design studies Complication rate for a particular disease can be measured QoC for particular disease can be assessed	The criteria might have a low threshold for morbidity to be labelled as MNM Some causes of MNM might be omitted (e.g. amniotic fluid embolism (AFE))
Intervention-based criteria	Interventions are used as a marker to identify MNM (e.g. ICU admission, emergency hysterectomy)	Simple to identify cases	Identifies only a fraction of MNM Biased by available resources
Organ dysfunction system criteria	Markers for organ failure are used to identify near-miss	Identify critically ill cases	Depends on resources available (laboratory, critical care monitoring) Difficult to be used in retrospective design

*(Adopted from Say, Souza and Pattinson, 2009)*

#### 1.4.5. WHO MNM identification criteria and approach for maternal health

For the purpose of standardisation of the identification methodology and criteria for MNM, the WHO Maternal Morbidity Working Group (2009) published a list of proposed identification criteria, and two years later the *WHO Near-Miss Approach for Maternal Health* was published as technical guidance (WHO, 2011).

As the earlier WHO (2004) systematic review concluded that organ-dysfunction criteria are the most useful identifiers of MNM, as organ failure precedes death, the WHO criteria are based on the concept of organ system dysfunction using markers of vital system failure (cardiovascular, respiratory, renal, hepatic, haematology, neurological, and uterine). These markers are mostly driven from the intensive care prognostic severity assessment score, called Sequential Organ Failure Assessment Score (SOFA) (Say, Souza and Pattinson, 2009), complemented by a set of clinical and management markers. Thus, the WHO criteria can be further divided into clinical, laboratory, and management criteria subcategories (**Table 1.2**) (Say, Souza and Pattinson, 2009). Furthermore, to optimise the identification of MNM, a list of medical conditions called potentially life-threatening conditions (PLTC) was proposed from which MNM could emerge. PLTC is defined as “clinical conditions, including diseases that can threaten a woman’s life during pregnancy and labour and after termination of pregnancy” (WHO, 2011).

*Table 1.2: The WHO list of PLTC and MNM*

Potentially life-threatening conditions	
Clinical conditions	Severe management indicators
Severe postpartum haemorrhage	Admission to ICU
Severe pre-eclampsia	Interventional radiology
Sepsis or severe systemic infection	Laparotomy (include hysterectomy, excludes C-section)
Ruptured uterus	Use of blood
Severe complications of abortion	
Near-miss criteria	
<i>Clinical</i>	
Acute cyanosis	Failure to form clots
Gasping	Jaundice in the presence of preeclampsia
Respiratory rate >40 or <6 bpm	Any loss of consciousness lasting > 12h
Shock	Stroke
Cardiac arrest	Uncontrollable fit/status epilepticus
Oliguria is no responsive to fluids or diuretics	Total paralysis
<i>Laboratory</i>	
PH< 7.1, Lactate>5mEq/mL	Creatinine ≥300 µmol/l or 3.5 mg/dl
Oxygen saturation <90% for ≥60 min	Acute severe thrombocytopenia (<50,000 platelets/ml)
PaO <sub>2</sub> <200mmHg	Bilirubin > 100 µmol/l or > 6.0mg/dl
<i>Management</i>	
Use of continuous vasoactive drugs	Transfusion of ≥ five units of blood/red cells
Intubation and ventilation not related to anaesthesia	Cardio-pulmonary resuscitation (CPR)
Dialysis for acute renal failure	Hysterectomy following infection or haemorrhage

Along with a standard definition, WHO (2011) issued the “MNM indicators” list to monitor maternal QoC, and these were later expanded to include process and outcome indicators (**Table 1.3**). The assessment of QoC was based on the criterion-based clinical audit, and the indicators measure the QoC as a ratio between the MNM and maternal deaths (MD). In fact, some of these indicators were used

previously; Filippi et al. (2005), for example, described the use of an MNM to mortality ratio in their work in Africa.

*Table 1.3: WHO indicators for evaluation of QoC using MNM*

Indicator	Description
<b>MNM outcome indicators</b>	MNM ratio: the number of MNM cases per 1,000 live births Severe Maternal Outcome Ratio (SMOR): The number of women with life-threatening conditions per 1,000 live births (LB). MNM: Mortality ratio (MNM:1 MD) the proportion between MNM cases and maternal deaths Mortality Index: The number of maternal deaths divided by the number of (MD and MNM), expressed as a percentage.
<b>Hospital access indicators</b>	The proportion of severe maternal outcome cases presenting with organ dysfunction or maternal death within 12 hours of hospital stay (SM012) SMO 12 mortality index
<b>Intra-hospital care</b>	Intra-hospital SMO rate (per 1000 live births) Intra-hospital mortality index
<b>Process and outcome indicators related to specific conditions</b>	The proportion of cases with a specific condition who received preventative measures The proportion of cases with a SMO Mortality related to the specific condition

Source: WHO (2011)

It was expected that this emergent WHO approach and recommended indicators would be a useful tool in assessing the QoC and the performance of healthcare systems in improving access to interventions to prevent and manage severe complications (WHO, 2011). It was also anticipated that they would increase the ease with which QoC can be compared across different countries (Say, Souza and Pattinson, 2009). Nonetheless, the uses and usefulness of these indicators have not yet been assessed. Furthermore, the applicability of the WHO criteria in low resources settings remains questionable (van den Akker et al., 2013).

## 1.5. Background about Oman

The study was conducted in the Sultanate of Oman, a high-income country located on the southeast coast of the Arabian Peninsula in Southwest Asia (World Bank, 2019). Oman is administratively divided into eleven governorates, each of which comprises local districts known as “*wilayat*”. Before 1970, it was considered an underdeveloped country. However, the nation has achieved tremendous development in the last few decades, and in the United Nations Development Programme ranked Oman as the most improved country in the world during the preceding 40 years, which was attributed to its extensive investment in health and education (United Nations Development Programme, 2010), and it continues to be in the category of very high human development (United Nations Development

Programme, 2018). The Oman healthcare system has demonstrated great achievements in healthcare services that are increasingly recognised internationally (Table 1.4).

Table 1.4: Oman fact sheet

Indicator	
Total population	4,559,963
Life expectancy at birth	76.9 years
Total fertility rate (births per women aged 15-49 years)	4.0
Infant mortality rate (per 1,000 live births)	9.5
Under five mortality rate (per 1,000 live births)	11.6
Maternal mortality ratio (per 100,000 live births)	20.2
Antenatal coverage	99.6%
Deliveries supervised by skilled personnel	99.3%

Source: Ministry of Health Annual Report (2017)

In terms of health system performance, by 2000 Oman was ranked first among 191 countries in its financial efficiency, and number eight in its overall performance (WHO, 2000). The nation moved from a position with the highest mortality rates in the region during the 1970s to be amongst the best performers, especially in reducing childhood mortality and achieving Millennium Development Goal 4 (National Centre for Statistics and Information, 2016). The health system in Oman ensures universal health coverage for Omani and non-Oman citizens (Department of Health Information and Statistics [DoH I&S], 2017).

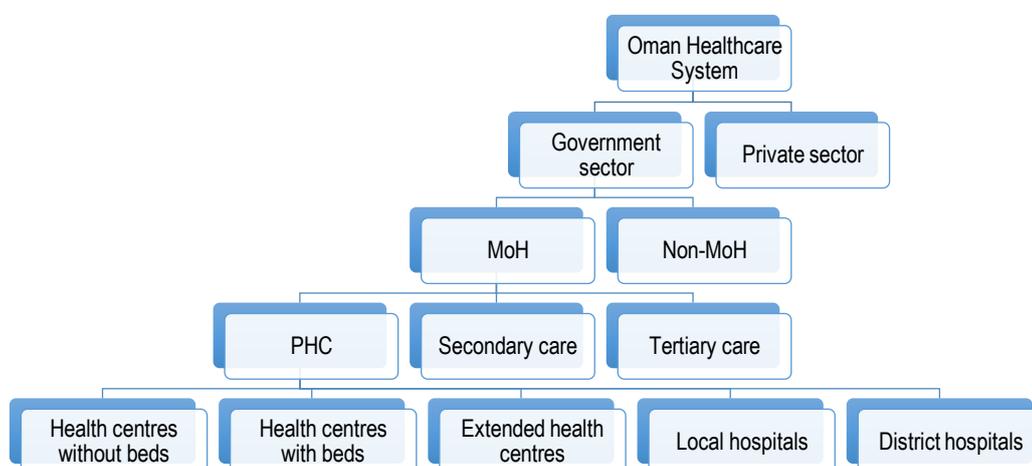
### 1.5.1. Demographic features

The Omani population is a young one, with approximately 15.3% and 36.8% of the population being aged under five years and under 15 years, respectively (DoH I&S, 2017). Females within the reproductive age group (15-49 years) represent about 25.8% of the total Omani population, and 52.1% of all Omani females (DoH I&S, 2017). The Total Fertility Rate has declined from 10.3 in 1985 to 4.0 in 2016.

### 1.5.2. Current health system

Figure 1.2 describes the structure of Oman's health system. The Omani Ministry of Health (MoH) is the main care provider and is responsible for stewardship and coordination of the health sector. The healthcare provided by other government organisations supplements MoH services, including Sultan Qaboos University Hospital, Armed Forces Hospital, Royal Oman Police Hospital, Diwan Health Services, and Petroleum Development Oman. Sultan Qaboos University Hospital acts as a teaching and public tertiary hospital, while the rest mainly cater to their

employees. The private sector still plays a small role in the provision of healthcare and it is licensed and monitored by the MoH. Healthcare delivery is based on primary healthcare (PHC) approach that provides preventive, promotive, and curative care (Alshishtawy, 2010).



*Figure 1.2: Health care delivery system in Oman*

The primary health care (PHC) is clearly linked with the secondary and tertiary care levels. It includes five categories of healthcare facilities. Secondary care is provided through regional hospitals, while tertiary care facilities are located mainly in the capital city, Muscat, and accept referrals from all over the country.

### **1.5.3. Maternal healthcare**

Oman has a developed well-structured maternity care package (Lewis and Stephenson, 2012). The integration of antenatal care into PHC and the free-of-charge service have increased the percentage of the antenatal coverage to over 99%. During registration, a client-based maternal record is issued to each woman. This record standardises the routine ANC visits for normal pregnancies and facilitates quick decision-making and action, particularly in emergency cases such as those wherein a woman arrives at another health facility that does not have any record of her. PHC level provides routine antenatal (ANC) and postnatal care (PNC), usually delivered by family doctors, nurses, and some midwives (**Table 1.5**).

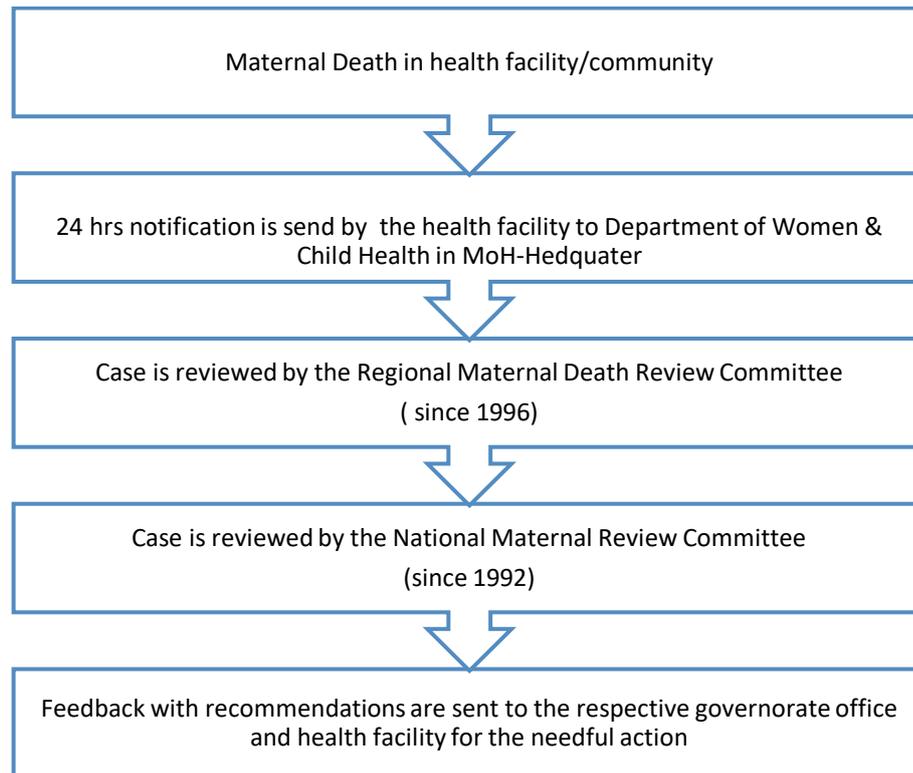
Table 1.5: Maternity service provision in Oman

Level of care	Description of services provided
<b>PHC (health centre, local hospital, district hospital)</b>	Care provided by family doctors, nurses and midwives and in some places by junior obstetricians First contact point for women with maternity care. Service of registration for ANC, risk assessment and delivery plan Routine standardised ANC and PNC for women within designated catchment area, including screening, immunisation, folic acid and iron supplementation, dating scan, health education Conduct low-risk deliveries in remote area
<b>Secondary care Regional hospitals in each governorate</b>	Care provided through specialist clinics by obstetricians and other specialities ANC for high-risk pregnancies Obstetric assessment for all pregnant women at least once during pregnancy Anomaly scan for all women Intrapartum services for all women
<b>Tertiary care Highly specialist care</b>	Provide similar services as level 2 Provide very specialised care for high risk pregnancies and foetal medicine for all over the country

Women with high-risk pregnancies are referred to secondary care in regional hospitals, which have obstetricians and other specialists. Those with severe complications are transferred to tertiary centres in Muscat. Deliveries are conducted in hospitals. Some health centres in very remote areas with trained midwives are allowed to conduct deliveries for normal pregnancies. Only spontaneous vaginal deliveries are allowed to take place in local or district hospitals, the rest should be referred to regional hospitals.

#### 1.5.4. Maternal mortality

Information on maternal mortality was not available until recently when the Maternal Death Surveillance System (**Figure 1.3**) was started in 1992. All maternal deaths occurring in or outside the health facility are notified within 24 hours. Retrospective maternity death data for 1991 was collected. National and regional maternal death committees were formed in 1992 and 1996 respectively for evaluating all notified maternal death cases, and accordingly formulating recommendations to prevent similar deaths. Death cases are notified regardless of the cause, and the data are cross-checked with the National Death and Births Statistic agency. This surveillance system was evaluated in 2011, and it was concluded it is unlikely that any maternal deaths are not captured by the system (Lewis, 2011).



*Figure 1.3: Maternal Death Surveillance System in Oman*

Each governorate in Oman has a Regional Maternal Death Committee headed by the Director General of Health Affairs, who is the highest health official in the governorate. The Committee members consist of a consultant obstetrician, senior midwife/staff nurse, senior family physician, and the head of each of the following sections: Woman and Child Health, Health Information and Statistics Section, and Quality Assurance.

The National Committee is chaired by the Director General of Primary Health Care and its membership consists of senior professionals from both the MoH and non-MoH sectors, including senior consultant obstetricians, one senior consultant physician, a senior midwife, and a senior family physician. Other members include the Director General of Quality Assurance, Director of Health Information and Statistics, Director of Department of Woman and Child Health (DWCH) and Head of Section of Woman Health. The Committee reports directly to the Minister of Health.

Prior to the National Committee meeting, each case should be assessed by two independent obstetricians and by a physician if the woman who died had a medical condition. Non-member experts can be requested by the Committee to review cases if necessary. For example, an infectious disease consultant reviewed all maternal deaths due to H1N1 (Swine Flu). The findings are then presented to the full

Committee where a consensus regarding the causes, classification of death (avoidable, non-avoidable or non-assessable) and the contributing factors is reached. After that, feedback with the findings and recommendations for practice is sent to the governorate in which the woman died.

## 1.6. Rationale for the study

### 1.6.1. Maternal mortality

While the number of reported maternal deaths in Oman is relatively small (6-27 maternal deaths annually), there is a large fluctuation in the MMR from year to year with unexplained sharp in 2002 (**Figure 1.4**). MMR declined from 27.4 maternal deaths per 100,000 live births in 1991 to 20.2 in 2017 (DoH I&S, 2017). Oman had a challenge in achieving MDG-5. According to UN estimates, Oman MMR declined from 30.0 per 100,000 live births in 1990 to 17.0 per 100,000 live births in 2015, with a 43.3% reduction against the 75% reduction expected (WHO, 2015b). Clearly it was generally challenging for countries with low MMR to achieve such reduction rates, which was evidenced in the estimated reduction rate for most of developed countries like the UK and Switzerland. In fact, Oman had a reduction rate that close to the one estimated for France, with 43.3% and 46.5% respectively.

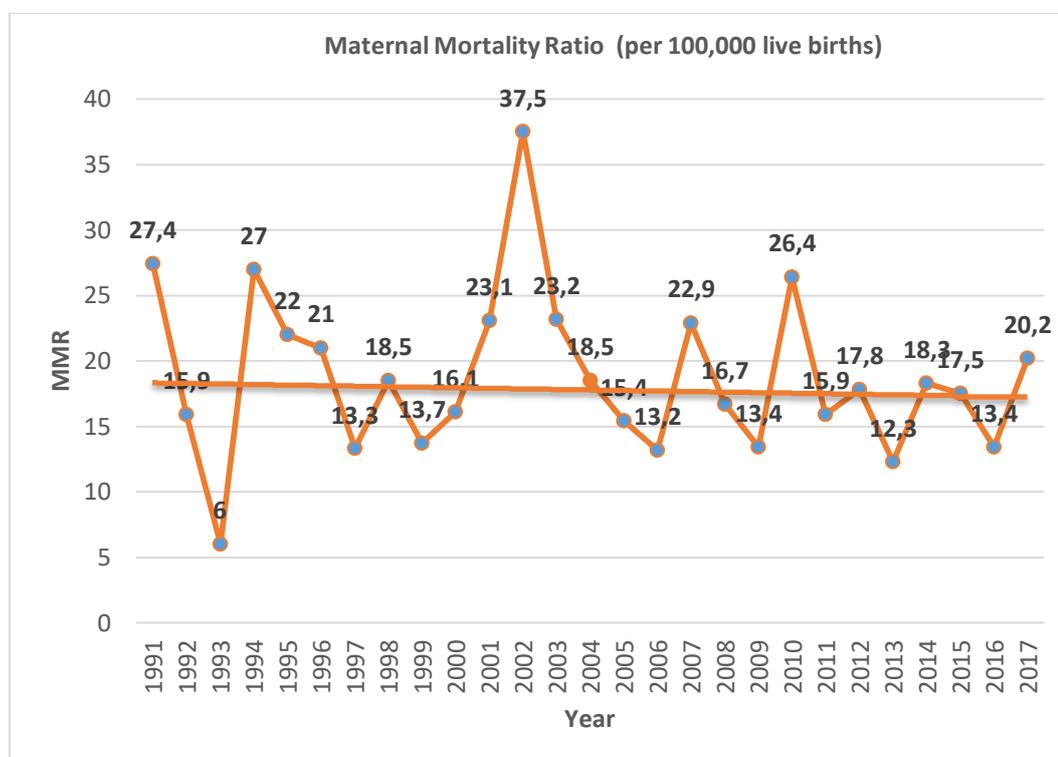
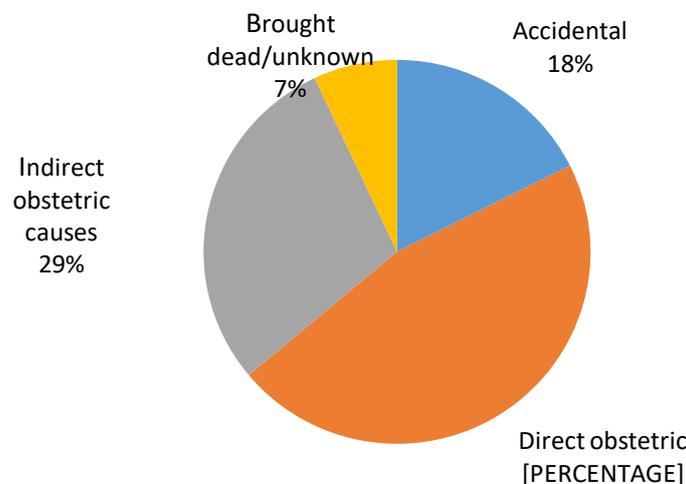


Figure 1.4: Oman's maternal mortality ratio (1991-2017)

However, evidence shows that Oman can further reduce its MMR. Analysis of maternal deaths data has shown that 46% of reported cases are direct maternal deaths, mostly due to preventable causes (**Figure 1.5**) (Al Abri, 2011; Department of Woman and Child Health, 2018). Moreover, the National Maternal Deaths Committee classified more than 50.0% of these deaths as avoidable deaths, with 45% of these deaths being related to factors attributable to the healthcare team (Department of Woman and Child Health, 2018).

Likewise, the finding of a recent analysis of reporting forms of National Maternal Review Committee demonstrated that 51% of maternal deaths were avoidable, with over 30% of deaths being due to health facility factors. Improving the quality of maternal health services can further reduce the maternal mortality ratio. It is likely that improving the QoC will further reduce the MMR. For a country with low number of maternal deaths, it will be beneficial to implement MNM review to strengthen maternal deaths review, and reinforce lessons learned from these reviews to improve QoC and ultimately reduce maternal mortality and morbidity (Pattinson and Hall, 2003; Knight et al., 2014a).



*Figure 1.5: Causes of maternal deaths in Oman (1991-2011)*

- *Error in coding of causes of maternal deaths*

Analysis of obstetric causes of death has revealed that haemorrhage accounts for 14.6% of deaths, sepsis for 14.6%, amniotic fluid embolism (AFE) for 6.4%, pulmonary embolism (PE) for 21.6%, and pregnancy-induced hypertension (PIH)/ eclampsia for 4.1% (Al Abri, 2011). However, these data have been challenged after external review. It is likely the figures of AFE, PE, and PIH unrealistic when

compared with worldwide figures (Lewis, 2011). It appears likely that AFE and PE are highly reported and PIH is underreported due to coding errors (Lewis, 2011).

### 1.6.2. Maternal morbidity

- *The burden of severe maternal morbidity is unknown in Oman*

Prior to conducting this study, the number of MNM events in Oman was unknown, as there was no standard recording system for cases with severe obstetric morbidity, as each healthcare facility uses different approaches. These cases were reported in a similar fashion to mild morbidity cases in the health information system using categories of International Classification of Diseases (ICD coding). Therefore, it was difficult to identify cases of severe maternal morbidity separately. For example, segregation of the unpublished morbidity data for the year 2014 (the year preceding the implementation of this study) showed that there were 108 postpartum haemorrhage cases, 329 obstructed labours, and 866 cases admitted with pre-eclampsia (**Table 1.6**) (DoH I&S, 2015). Such data is not informative about the severity of morbidity.

Furthermore, there was a probability that these figures were higher, considering the coding errors mentioned earlier, and the disease transition that the nation faces, with a high burden of non-communicable diseases (particularly diabetes mellitus). Also, the multiparty is still common, with a preference for large family sizes resulting in a high percentage of repeated caesarean sections (Kazmi et al., 2012).

*Table 1.6: In-patient morbidity due to pregnancy and childbirth in Oman, 2014*

ICD-10 Code	Morbidity Conditions	Total
	Abortions	5,983
	Other pregnancies with abortive outcome	2,278
	Oedema, proteinuria and hypertensive disorders in pregnancy, childbirth and puerperium	866
	Placenta praevia, premature separation of placenta and antepartum haemorrhage	417
	Other maternal care related to foetus and amniotic cavity and possible delivery problems	5,065
	Obstructed labour	329
	Postpartum haemorrhage	108
	Other complications of pregnancy and delivery	13,989
	Complications predominantly related to puerperium and other maternal conditions	1,132

Source: DoH I&S (2015)

According to the DoH I&S (2017), the calculated morbidity due to pregnancy, childbirth, and puerperium was around 10.7- 12.8% of total in-patient morbidity in

the last ten years. In the year 2017, the prevalence was estimated to be 476 per 10,000 women (aged 15-49 years).

### **1.6.3. Strategic plan**

Recently, the MoH led a project of health system reform to improve the quality and efficiency of the health system. A long-term plan (Health Vision 2050) was put into place which includes a strategy for women and child health (MoH, 2014). The first goal of this strategic plan is to “end preventable maternal and newborn deaths”. It also seeks to strengthen the surveillance system by counting “every mother and newborn with program tracking and accountability through establishment of a strong surveillance system for future audit and recommendations”, improving QoC through enhancing “the quality of maternal and newborn care” as strategic actions to achieve this goal (Directorate General of Planning and Research, 2015).

## **1.7. Problem statement and importance of the study**

Considering the above facts and the small number of maternal deaths, there is a need to establish MNM review in Oman to complement maternal deaths review in order to make recommendations to improve maternity services Oman, which is currently in stage four of obstetric transition (Souza et al., 2014), with a low number of maternal deaths, good access to maternity care, and a high burden of non-communicable disease. These facts necessitate a focus on improving QoC. Evidence from developed and developing countries indicates that MNM review is an effective strategy in improving maternal and newborn QoC (Halliday et al., 2013; Knight et 2014; Marr, Lennox and McFadyen, 2014; Vandenberghe et al., 2017; Lazzerini et al., 2018). Implementing a near-miss system has been recommended to improve the quality of care in Oman since 2011 (Lewis, 2011; Lewis and Stephenson, 2012).

## **1.8. Study aim, objectives, and research questions**

The primary aim of this PhD study is to introduce MNM review to Oman in order to complement maternal deaths review and provide data on which to base recommendations for the improvement of maternity care in Oman.

The specific objectives were to:

1. Introduce MNM review to Oman at hospital and national levels.
2. Determine the incidence of MNM and the MNM indicators for Oman.

3. Identify the underlying causes of and contributory conditions to MNM.
4. Assess the QoC for women with MNM and identify priority areas for which improvements could be made.
5. Identify factors associated with MNM (organisational, medical team, and patient-related).
6. Formulate recommendations for the improvement of QoC in maternity services.

The following research questions were formulated to fulfil the study objectives:

- What is the incidence of maternal “near-miss” in Oman? What are the values of MNM indicators for Oman?
- What are the underlying causes of MNM?
- What are the contributory conditions to MNM?
- What is the standard of care the women with MNM received?
- What are the factors associated with MNM events?

## 1.9. Thesis structure

This thesis is structured into nine chapters, as described below.

**Chapter 1 (Introduction):** highlights the burden of maternal mortality and morbidity, introduces the concept of MNM, and gives an overview of the research conceptualisation and organisation.

**Chapter 2 (Literature Review):** presents the systematic review that was performed on the existing literature to identify the approaches used to implement MNM review and the indicators used to measure the QoC to inform the study methodology. The results are presented in a narrative format and complemented with tables and graphs. The included studies are listed in **Annex 1**. The chapter synthesises and discusses the findings of the review and concludes with selection of approach to be used to implement the study.

**Chapter 3 (Methodology):** describes the study design, selection of participating healthcare facilities, and the data collection process, including the identification and review of MNM. It also describes the criteria used to identify MNM and the process of development of these criteria. The chapter further explains quality assurance, and the processing and analysis of data. It concludes with consideration of ethical issues pertaining to this study.

Chapters 4 to 7 present the results of the study. They were structured according to the study objectives.

**Chapter 4 (Characteristics and Indicators of MNM):** related to objective 1, reports the incidence and indicators of MNM. It also describes the characteristics of women with MNM.

**Chapter 5 (Underlying Causes of MNM, Identification Criteria, and Description of Events):** related to objective 2, presents the reported causes of MNM by healthcare providers from the participating healthcare facilities. It also describes the MNM events.

**Chapter 6 (Causes of and Conditions Contributing to MNM According to Review Committees):** related to objective 2, presents and compares the causes of and contributory conditions to MNM as assigned by the reviewers.

**Chapter 7 (Quality of Care and Associated Factors in MNM):** related to objectives 3 and 4, reports the standard of care provided to MNM and factors associated with MNM.

These results are presented in narrative format and complemented with tables and graphs. Supplementary information is presented in the annexes when necessary.

**Chapter 8 (Discussion):** analyses and discusses the study results. It begins with a summary of the main findings then provides contextual interpretations of these findings, relating and comparing them with previous literature. It addresses the study strengths and limitations.

**Chapter 9 (Conclusion):** highlights the key implications of the study outcomes for practice and research at the international level and for Oman. The chapter concludes the thesis by listing key recommendations to improve maternal health in Oman as well key findings, thus fulfilling the final objective (5) of the study.

## **1.10. Summary**

Despite global commitment to improve maternal health, maternal mortality and morbidity are still unacceptably high. Ensuring QoC is a core strategy to achieve the sustainable development goals related to maternal and new-born health. MNM is a woman who nearly died, but survived complications during pregnancy, childbirth, and up to 42 days of termination of pregnancy. MNM review was introduced to

complement maternal deaths review to provide recommendations to improve QoC, in particular in countries with few maternal deaths.

Oman is a high-income country with a well-established maternal deaths review system. The number of maternal deaths is considered relatively low. However, there is no steady reduction in MMR, and most deaths that do occur are considered preventable. Moreover, factors related to healthcare team providing the care were identified as major factors associated with these deaths. The burden of severe maternal morbidity and MNM is unknown, as there is no standard recording system in the country.

Consequently, this research introduces MNM review to complement maternal deaths review in order to provide more data to improve the QoC. The research will explore the causes of, contributory conditions, and factors associated with MNM. It will also assess the QoC provided to women with MNM, and provide recommendations for further improvement in maternity care in future.

The next chapter presents the systematic review conducted to explore the methods used to implement MNM audit/review and the indicators used to measure the QoC.

## 2. Literature Review

This chapter presents the systematic review that was conducted to explore the literature to identify the methods used to implement MNM audit/review and the indicators used to assess the QoC.

The chapter describes the methodology of the review and presents the results in a narrative, using narrative synthesis, illustrated by tables and graphs. In the discussion section, the major findings of the review are presented and discussed. These findings were used to inform the methodology of the study

### 2.1. Aim and objectives of the review

Several reviews of MNM have been conducted since the early 2000s (Say, Pattinson and Gulmezoglu, 2004; Filippi et al., 2009; Reichenheim et al., 2009; Ronsmans, 2009; Van Roosmolán and Zwart 2009; Pollock, Rose and Dennis, 2010; Kay, Kakaire and Osinde, 2011; Alder et al., 2012; Tuncalp et al., 2012). The systematic review by Filippi et al. (2009) focused on delays in seeking and accessing care identified via MNM review. Other reviews examined the definition of, identification criteria for, and use of MNM (Reichenheim et al., 2009; Ronsmans, 2009). The last group of studies examined the prevalence of MNM in an attempt to use it as a measure to compare QoC across different parts of the world (Say, Pattinson and Gulmezoglu, 2004; Pollock, Rose and Dennis, 2010; Kay, Kakaire and Osinde, 2011; Alder et al., 2012; Tuncalp et al., 2012a). Nonetheless, there are as yet no clear estimates of the MNM prevalence, and a wide range of prevalence has been reported due to variations in the criteria used for the identification of MNM, which makes comparison a challenge. While the prevalence is important, it reflects only the magnitude of the severe morbidity, without indicating the reasons behind it. Additional measures therefore need to be used to have a better understanding of QoC provided.

As explained in the previous chapter, WHO recommended a set of MNM indicators to assess QoC, but the uses and usefulness of these indicators have not yet been assessed. The aim of this review is to explore the literature to identify publications on the use of MNM to assess QoC, and how such assessment was done to inform the methodology of the study. The specific objectives of the review were:

- To examine the methods used to implement MNM audit/review for evaluating MNM.
- To identify MNM-related indicators used to measure QoC.

## 2.2. Methodology of the review

The review utilised a systematic review methodology in order to reduce bias and ensure future replicability. The following sections describe the research questions and screening process.

### 2.2.1. Research questions

The research questions were formulated based on the objectives of the review, and are presented in **Table 2.1**.

*Table 2.1: Research questions guiding the systematic review*

<b>Methods</b>	<p><b>What methods have been used for implementing MNM audit/review to assess QoC?</b>  <b>Where and how have these methods been implemented?</b>  <b>What are the strengths and limitations of these methods?</b></p>
<b>Indicators</b>	<p>What are the MNM related indicators used in assessing the QoC?          To what extent have the WHO (2009/2011) recommended MNM indicators been used in assessing QoC?          What are the limitations of the WHO-recommended MNM indicators in assessing QoC?          To what extent do the MNM criteria used affect the selection of these indicators?          Can the indicators (a) MNM ratio, (b) MNM morality ratio, and (c) mortality index be calculated from the data presented in MNM publications?</p>

### 2.2.2. Search strategy

A search strategy was developed using medical search headings (MeSH) and terms and their synonyms under three main categories related to the objectives of the review. These MeSH headings and terms were identified after reviewing previous articles on the subject (**Table 2.2**)

*Table 2.2: MeSH headings and terms used in the search strategy*

	<b>Mesh heading</b>	<b>Terms</b>
<b>MNM</b>	Pregnancy complication Maternal mortality Maternal death	MNM obstetric near-miss Severe acute maternal morbidity Near miss morbidity
<b>Evaluation of quality (process and outcome assessment)</b>	Epidemiological methods Comparative studies Evaluation studies	Outcome and process assessment
<b>Intervention criteria for MNM</b>	Intensive care unit Emergency hysterectomy	Emergency hysterectomy Intensive care unit

The MeSH headings and terms were used in combination or isolation using Boolean terms “OR”/ “AND”, as illustrated in **Figure 2.1**. The search was for the period

January 2009 to August 2018 (The 2009 was selected as starting point because, the WHO approach and MNM indicators were published during this year as mentioned in chapter 1). The search strategy was applied in five computerised databases: Medline through Ovid, Web of Science, Scopus, CINHALL Pulse, and Global Health. The search strategy also included searching references in the retrieved articles.

**MeSH heading related to maternal morbidity and mortality**

(Pregnancy complications.mp. or exp Pregnancy Complications/) OR Maternal Mortality/ OR Maternal Death/ OR maternal morbidity.mp.

**AND**

**MeSH heading and terms related to process and outcome assessment**

Epidemiologic methods/ or comparative studies.mp. OR evaluation studies.mp. OR (outcome and process assessment).mp.

**OR**

**Intervention criteria for MNM criteria**

[(Intensive Care Units/ OR Hysterectomy/) AND maternal morbidity.mp.] OR [(Intensive Care Units/ OR Hysterectomy/) AND pregnancy complication] OR Emergency peripartum hysterectomy OR emergency obstetric hysterectomy

**OR**

**Terms related to MNM**

MNM\*.mp. OR obstetric near miss\*.mp. OR severe acute maternal morbidity.mp. OR near-miss morbidity.mp.)

*Figure 2.1: Search strategy*

### **2.2.3. Screening**

The researcher and an academic colleague screened each title and abstract independently, after that the full text of the retrieved papers was screened. When there was disagreement regarding the relevance of a publication, senior researchers (the first or second supervisor) reviewed the full paper and made a final decision.

### **2.2.4. Inclusion and exclusion criteria**

Publications were included if they were in the English language and described methods to use MNM to assess QoC, or used indicators related to MNM to assess QoC. Publications were excluded if they were conference abstracts, editorial

comments, commentaries, book chapters, study protocols, narrative reviews, or qualitative studies. Research that focused on mortality, perinatal/neonatal outcome, and one type of morbidity; or that only examined mainly trends, association, or risk factors for MNM were also excluded. Furthermore, citations that described, compared, or validated criteria only to define MNM were excluded.

### **2.2.5. Studies identified for inclusion in the review**

The primary search produced 6,964 publications from databases and one additional paper from the search of references; of those 1,454 were duplicates and 5,305 of the remaining papers were excluded after screening their titles and abstracts. Thus, 206 articles were subjected to full-text screening, and 98 of these were found to meet the inclusion criteria and were therefore included in the review. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) tool was used to report the screening process (**Figure 2.2**).

### **2.2.6. Data extraction and synthesis**

The studies were examined to identify their strengths and limitations, and the applicability of the indicators. Several tools were used for the critical appraisal of the quality of research. Most of these tools are more applicable for research that focuses on clinical or intervention research, such as the GRADE tool. GRADE grades the quality of evidence based on the study design. It takes into account the risk of bias, imprecision, inconsistency, indirectness, and publication bias. This approach is not appropriate for this kind of review (Atkins et al., 2004). We therefore adopted the Critical Appraisal Skills Programme (CASP) as a tool for the quality assessment (QA) of included studies (Critical Appraisal Skills Programme, 2016). The CASP programme treats different types of research in the same manner, by asking a number of questions that address three broad issues:

- Study validity (focus issue, recruitment of participants, bias)
- The clarity and precision of results
- Limitations and generalisation of the findings

These questions were adapted, and a score of (0-2) was allocated for each answer. A grade was assigned to each study indicating the quality of the study based on the total score: high (22-18), medium (10-17), and low (<10).

Using a pre-designed form, relevant information from the included studies related to study reference, design, location, objectives, and criteria used were recorded. Data

collected by these studies and major findings were also extracted. The indicators used to measure the QoC and the range of these indicators was reported. These indicators were divided into those described by WHO and other indicators. Those described by WHO were subdivided into outcome and process indicators. **Annex 1** presents a summary of included studies.

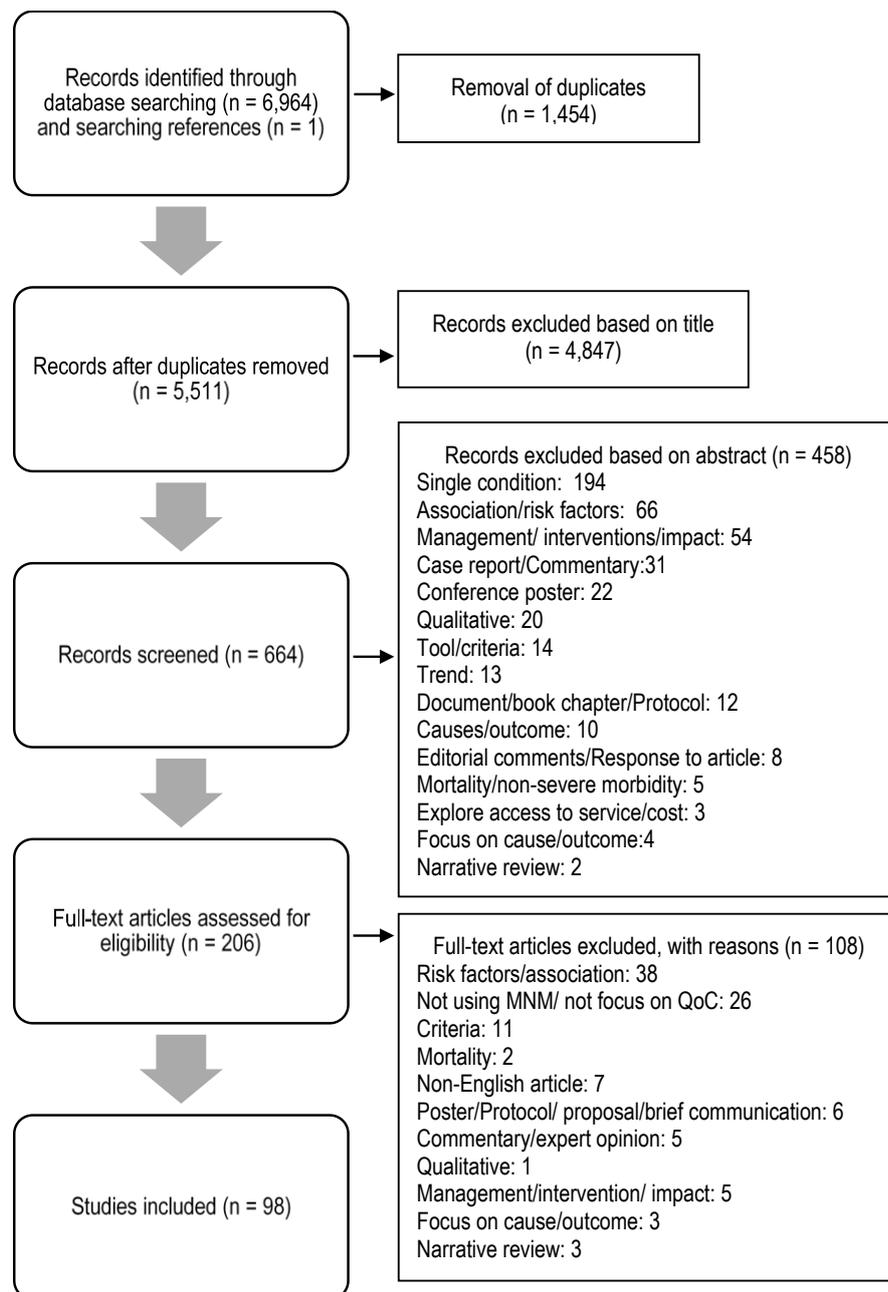


Figure 2.2: Screening process (PRISMA)

## 2.3. Results

The results of this review are presented in terms of the included publications, settings and participants, the definition of maternal MNM, criteria for identification of MNM, and findings related to the research questions.

### 2.3.1. Description of included citations

Of the 98 identified publications, five were case studies describing country approaches to implementing an MNM review to assess QoC (Baltag, Filippi and Bacci, 2012; Bhattacharyya, Srivastava and Knight, 2014; Knight et al., 2014; Marr, Lennox and McFadyen, 2014; Vandenberghe et al., 2017). The remaining 93 papers included:

- 3 systematic reviews (Pollock, Rose and Dennis, 2010; Tuncalp et al., 2012; Kay, Kakire and Osinde, 2011)
- 4 secondary analyses (Bouvier-Colle et al., 2012; Tamura et al., 2012; Gorbman et al., 2014; Cecatti et al., 2015)
- 65 (the majority) of the primary research studies were cross-sectional studies (CSS), of which 48 were prospective, 17 were retrospective and one study used both prospective and retrospective data (Ghazal-Aswad et al., 2013)
- 13 were cohort studies
- 6 were case-control studies
- 1 study was a prospective CSS with nested case control (Galvao et al., 2014).

Based on the World Bank (2019) classification, 73 (74.5%) of the retrieved papers were from low and middle-income countries (LMIC), 20 (20.4%) were from high-income countries (HIC) and the remaining five (5.1%) were carried out in both LMIC and high-income countries, including the three systematic reviews, the WHO Multicounty Survey (Souza et al., 2013), and a survey conducted in five countries in Europe and Central Asia.

. A map showing the locations of the included studies is shown in **Figure 2.3**.



Figure 2.3: Geographic distribution of included studies

### 2.3.2. Setting and participants

The studies described the characteristics of the settings as well as the included participants. The majority were facility-based, mainly from tertiary healthcare facilities, except one study conducted in four districts in Thailand, where the cases were identified in the community and confirmed in healthcare facilities (Luexay et al., 2014). There were 13 national studies, six of which collected primary data (van Dillan et al., 2010; Souza et al., 2012; Hadded et al., 2014; Pacagenella et al., 2014; Cecatti et al., 2016; Oladapo et al., 2016), and the remaining used existing hospital databases (Bouvier-Colle et al., 2012; Donati, Senatore and Ronconi, 2012; Lutomomski et al., 2012; Dias et al., 2014; Grobman et al., 2014; Chantry et al., 2015; Soma-Pillay et al., 2015).

After excluding the three systematic reviews and the five case study papers, 40 out of the remaining 90 papers (44.4%) included women irrespective of the gestational age and up to 42 days post termination of pregnancy, while five studies included women up to seven days postpartum (Jabir et al., 2013; Souza et al., 2013; Bashour et al., 2015; Mazhar et al., 2015; Ghazivakili et al., 2016). Dias et al. (2014) and Karolinski et al. (2010) restricted the inclusion criteria to women of more than 22

weeks of gestation. Soma-Pillay et al. (2015) excluded cases of abortion and ectopic pregnancy from their survey. Bibi et al. (2010) and Norhyati et al. (2016) focused on MNM events during the postpartum period only. The remaining 40 studies (44.4%) did not clearly define the gestational age.

### 2.3.3. Definition of MNM

Overall, studies defining MNM as a woman who nearly died but survived complications. Roost et al. (2009, p.1211) described MNM as woman with “immediately life-threatening, pregnancy-related complications that was resolved by chance or by medical care”. Similarly, Murphy et al. (2009, p.35) referred to MNM as cases with severe maternal morbidity and defined them as “who without timely intervention may have risked maternal death”. The studies using ICU admission as an identification criterion defined MNM as a woman admitted to ICU during pregnancy, childbirth, or the postpartum period (Oliveria Neto et al., 2009; Karolinski et al., 2010; Lawton et al., 2010; Aldawood et al., 2011; Donati, Senatore and Ronconi, 2012; Chantry et al., 2015; Gombar, Ahuja and Jafra, 2014; Lawton et al., 2014; Mansoor, 2014).

Different terminologies were used interchangeably with the term MNM, including obstetric morbidity, obstetric near-miss, severe acute maternal morbidity (SAMM), and severe maternal morbidity. On the other hand, three other studies used the SAMM to refer to potentially life-threatening conditions (Galvao et al., 2014; Pacheco et al., 2014; Madeiro et al., 2015). Lotufo et al. (2012) used “SAMM” for cases admitted to the ICU, and “MNM” for cases fulfilling the WHO criteria.

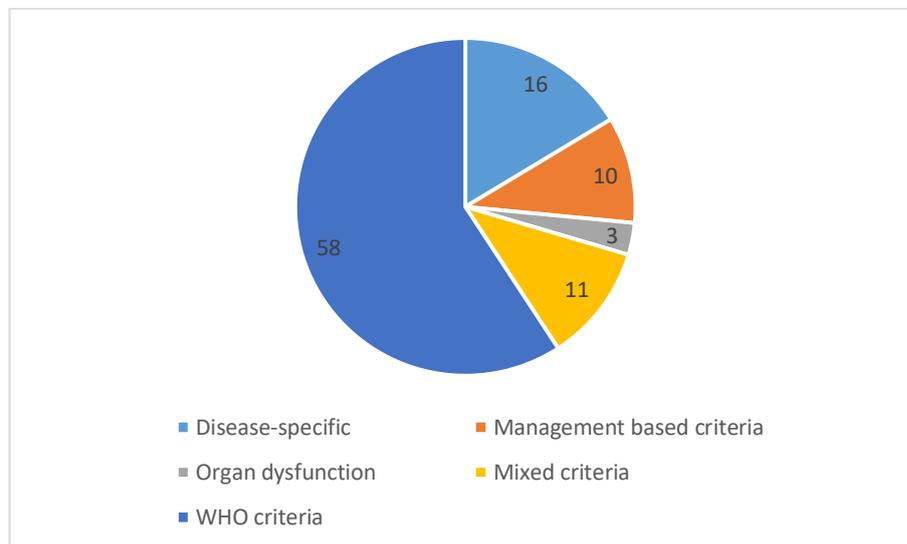
*Table 2.3: Terms used to describe MNM*

Term used to describe MNM	Study
<b>Obstetric morbidity</b>	Siddiqui, Soomro and Shabih-UI-Hasani (2012)
<b>Obstetric MNM</b>	Kaira and Kachwaha (2014) and Simsek et al. (2013)
<b>Severe maternal morbidity</b>	(Murphy et al., 2009; Karolinski et al., 2010; Morase et al., 2011; Bourvier Colle et al., 2012; Lutomski, Greene and Byme, 2012; Gorbman et al., 2014; Haddad et al., 2014; Marr, Lennox and McFadyen, 2014; Nadari et al., 2015; Reid and Creanga et al., 2015)
<b>Severe acute maternal morbidity” (SAMM)</b>	Oliveira Neto et al., 2009; Lawton et al., 2010; van Dillan et al., 2010; Amaral et al., 2011; Rabia et al., 2011; van den Akkar et al., 2011; Bibi et al., 2012; Ghazal-Aswad et al., 2013; Lawton et al., 2014; Mansoor, 2014; Tamura et al., 2012; Nielsen et al., 2013a; Cecatti et al., 2015

### 2.3.4. Criteria for identification of MNM

Five main categories of criteria for identification of MNM were identified in this review: (1) disease specific criteria; (2) management-based criteria; (3) organ

dysfunction criteria; (4) mixed criteria; and (5) WHO criteria. (These criteria were described in chapter 1 (section 1.4.4)). After excluding the three systematic reviews, the WHO criteria were the most commonly used criteria across all studies 58 (55.8%) (**Figure 2.4**).



*Figure 2.4: Distribution of included articles based on the MNM identification criteria*

#### **2.3.4.1. Disease-specific criteria**

In disease-specific criteria, specific diseases are used as starting points. After that, morbidity is defined for each disease by identifying its complications. Of 16 papers (16.8%) using disease-specific criteria, four presented the approach used to implement MNM surveillance and review, in the UK, Belgium, Moldova, and India (Baltag, Filippi and Bacci, 2012; Knight et al., 2014; Bhattacharyya, Srivastava and Knight, 2014; Vandenberghe et al., 2017). The remaining 12 were studies with half of them utilised the criteria developed by Filippi et al. (2005) in Africa. Siddiqui, Soomro and Shabih-UI-Hasani (2012) used modified Waterstone criteria, developed and piloted by Waterstone et al. (2001) in the UK. The rest developed their own criteria (Rabia et al., 2011; van den Akker et al., 2011; Tamura et al., 2012; Ghazal-Asawad et al., 2013; David et al., 2014). This means that there was a variation in the selected disease or severe morbidities used to identify or define MNM, as illustrated in **Table 2.4**. Severe haemorrhage, hypertensive disorder of pregnancy, and sepsis were the most commonly used morbidities to identify MNM, as they were used in all 12 studies.

Nonetheless, there is a wide variation in defining these conditions between the studies. For example, severe pre-eclampsia and eclampsia were defined more

precisely in the Waterstone criteria used by Siddiqui, Soomro and Shabih-UI-Hasani (2012) compared to the rest of the studies. The other observation worth noting is that these studies mainly focus on obstetric complications. Anaemia and malaria were the only two medical disorders included among the diagnostic conditions to identify MNM. Anaemia was listed in the Fillippi criteria which used in eight of the studies, while malaria was listed as a severe morbidity in the criteria used by David et al. (2014) in Mozambique. Van den Akker et al. (2011) considered the use of intravenous anti-malaria treatment as a marker for severe sepsis in their work in Malawi.

#### *2.3.4.2. Management-based criteria*

The management-based criteria used specific interventions to define and identify MNM, such as admission to intensive care (ICU), hysterectomy, etc. Ten (9.5%) studies reported using management-based criteria, nine of which used ICU admission. These studies based their definition and criteria for MNM as a woman being admitted to ICU during pregnancy, childbirth, or in the postpartum period. Ozimek et al. (2014) in the US used the identification criteria proposed by the Centres for Disease Control and Prevention (CDC) using the International Classification of Diseases, 9<sup>th</sup> Revision (ICD-9 Code) for four interventions; ICU admission, prolonged length of hospital stay ( $\geq 4$  days for vaginal delivery and  $\geq 6$  days for caesarean delivery, blood transfusion of four units of packed red blood cells, and hospital readmission within 30 days of discharge.

#### *2.3.4.3. Organ dysfunction criteria*

In organ dysfunction criteria, markers for organs failure are used to identify MNM. In this review three (3.2%) studies used organ dysfunction, from Scotland, Ireland and India (Murphy et al., 2009; Marr, Lennox and McFadyen, 2014; Chaudhuri and Nath, 2018). All used Mantel criteria to identify MNM cases; these criteria were developed and piloted by Mantel et al. (1998) in South Africa to define MNM using markers for major systems' failure.

#### *2.3.4.4. Mixed criteria*

In eleven studies (11.6%), a mixture of markers from the above criteria were used to identify MNM. Using disease-specific criteria together with management-based criteria was the most common identified combination, as used by six studies (Souza et al., 2010; van Dillan et al., 2010; Bibis et al., 2012; Bouvier-Colle et al., 2012; Lutomski, Greene and Byrne, 2012; Cecatti et al., 2015). Four studies used a combination of management and organ dysfunction criteria (Karolinsk et al., 2013;

Gorbman et al., 2014; Assarg et al., 2015). Two studies used a mixture of disease and organ dysfunction criteria (Amaral et al., 2011; Morases et al., 2011). Reid and Creanga (2018) used a combination of disease-specific, management, and organ dysfunction markers by selecting a number of specific codes from ICD-9.

#### 2.3.4.5. WHO criteria

The WHO criteria were described in chapter 1 (Table 1.2). They were used by 58 (55.8%) of included studies. Eight used a modified version based on local contexts (Nelissen et al., 2013a; Luexay et al., 2014; Rulisa et al., 2015; Kalisa et al., 2016; Mhammedi et al., 2016; Herkolots et al., 2017; Mbachu et al., 2017; Sayingzoga et al., 2017). One study applied only the clinical part of the WHO criteria (Oladapo et al., 2015). These studies reported a challenge in applying the WHO criteria due to a lack of required resources, such as laboratory services, forcing them to use modified versions of the criteria. Ghazivakili et al. (2016) reported a challenge with using the whole WHO criteria, and noted that they could have underestimated the incidence of MNM and MNM indicators. Even using a modified version, Luexay et al. (2014) recorded the same observation and assumption of underestimation of the obtained results.

It seems also that use of the WHO approach is more common in LMIC countries than in high-income countries. Surprisingly, among these 58 studies, only three were conducted in a HIC countries, each of them in a single hospital in Australia by the same research team (Jayartnam et al., 2011, 2016, 2018)

*Table 2.4: Diseases and markers used to define MNM in disease specific criteria*

Study	Diseases and markers used to define and identify MNM
<b>Adeoye, Onayade and Fatusi (2013)</b>	Filippi et al. (2005) criteria Haemorrhage: Shock, emergency hysterectomy, coagulation defects, blood transfusion of two or more litres of blood.
<b>Adeoye, Onayade and Fatusi (2015)</b>	Hypertensive disorders in pregnancy: Eclampsia and severe pre-eclampsia. Dystocia: Uterine rupture and impending rupture.
<b>Ali et al. (2011)</b>	Infection: Hyperthermia or hypothermia, or a clear source of infection and clinical signs of shock.
<b>Almerie et al. (2010)</b>	Anaemia: Low haemoglobin level of less than 6g/dl in woman without haemorrhage or clinical signs of severe anaemia in woman without haemorrhage.
<b>Naz et al. (2014)</b>	
<b>Roost et al. (2009)</b>	
<b>Simsek et al. (2013)</b>	
<b>Siddiqui, Soomro and Shabih-Ul-Hasani (2012)</b>	Waterstone (2001) criteria Severe pre-eclampsia: BP 170/110 mmHg on two occasions 4 hours apart or > 170/110 mmHg once with $\geq 0.3$ g in 24 proteinuria or $\geq$ on dipstick OR Diastolic BP > 90 mmHg plus proteinuria on one occasion plus one of the following symptoms (visual disturbances, epigastric/right upper quadrant pain or tenderness,

Study	Diseases and markers used to define and identify MNM
	<p>thrombocytopenia, pulmonary oedema).</p> <p>Eclampsia: Convulsion during pregnancy or in the first ten days postpartum, together with at least two of the following features within 24 hours of experiencing convulsions (hypertension <math>\geq 170/110</math> mmHg), proteinuria, thrombocytopenia (<math>&lt; 100 \times 10^9/l</math>), increase in aspartate aminotransferase (<math>\geq 42U/l</math>).</p> <p>HELLP syndrome: Haemolysis, raised liver enzyme activity and low platelets.</p> <p>Severe haemorrhage: Blood loss <math>&gt; 1500</math>, peripartum fall in Hb <math>\geq 4</math> g/dl or acute transfusion of <math>\geq 4</math> units of blood.</p> <p>Uterine rupture: Acute dehiscence of the uterus leading to emergency delivery of the infant.</p> <p>Severe sepsis: Sepsis associated with one of the following: organ dysfunction, hypoperfusion, or hypotension.</p>
<b>David et al. (2014)</b>	<p>Eclampsia: Convulsion during pregnancy or in the first 48 hours postpartum together with hypertension and proteinuria.</p> <p>Severe haemorrhage: Profuse vaginal bleeding with hypovolemic shock, systolic blood pressure <math>&lt; 90</math> mmHg and need for blood transfusion.</p> <p>Severe sepsis: Two or more of the following signs; temperature <math>&gt; 38^\circ C</math> or <math>&lt; 36^\circ C</math>, heart rate <math>&gt; 100</math> beats/minutes, respiratory rate <math>&gt; 20/min</math>, white blood count <math>&gt; 17 \times 10^9/l</math>, clinical signs of peritonitis.</p> <p>Uterine rupture: Acute dehiscence of the uterus which needs a blood transfusion and/or surgical repair and/or hysterectomy.</p> <p>Severe malaria: Malaria with coma or convulsions and need of blood transfusion in the pregnant, puerperal, or post-abortion periods.</p>
<b>Ghazal-Aswad et al. (2013)</b>	<p>The following conditions were included without mentioning a definition:</p> <p>Eclampsia: Convulsions during pregnancy or in the first ten days postpartum, together with at least two of the following features within 24 hrs of experiencing convulsions (hypertension <math>\geq 170/110</math> mmHg, proteinuria, thrombocytopenia, increased aspartate aminotransferase).</p> <p>HELLP syndrome: the presence of haemolysis, raised liver enzyme activity, and low platelets.</p> <p>Severe pre-eclampsia: BP of <math>170/110</math> mmHg on two occasions four hr apart, or <math>&gt; 170/110</math> mmHg plus proteinuria or diastolic pressure <math>&gt; 90</math> mmHg plus proteinuria on one occasion in addition to either oliguria, visual disturbance, epigastric/right upper quadrant pain or tenderness, thrombocytopenia or pulmonary oedema.</p> <p>Severe haemorrhage: Estimated blood loss of <math>&gt; 2,000</math> ml, fall in Hb of <math>4.0</math> g/dl or blood transfusion of <math>\geq 4</math> units</p> <p>Uterine rupture: Acute dehiscence of the uterus leading to emergency delivery of the infant.</p> <p>Severe sepsis: Systematic response to infection with two or more of the following; temperature <math>&gt; 38^\circ C</math> or <math>&lt; 36^\circ C</math>, heart rate <math>&gt; 100</math> beats/minutes, respiratory rate <math>&gt; 20/min</math>, or PaCO<sub>2</sub> <math>&lt; 32</math> mmHg, white blood count <math>&gt; 17 \times 10^9/l</math> or <math>&lt; 4 \times 10^9/l</math> or <math>&gt; 10\%</math> immature forms, or bacteraemia or positive swab culture. Also, if sepsis is associated with organ failure.</p> <p>Deep venous thrombosis.</p> <p>Pulmonary embolism.</p>
<b>Rabia et al. (2011)</b>	<p>Severe haemorrhage: Severe haemorrhage leading to <math>&gt; 4</math> units of blood transfusion, caesarean section or hysterectomy.</p> <p>Severe hypertension: imminent eclampsia and eclampsia.</p> <p>Dystocia: Obstructed labour leading to caesarean section or uterine rupture.</p> <p>Severe sepsis: Peritonitis, septicaemia, foul smelling following delivery or abortion leading to hospitalisation or visceral injury.</p>
<b>Tamura et al. (2012)</b>	<p>Included the following conditions, but without defining them: (1) haemorrhage (2) obstructed labour (3) hypertensive disorders (pre-eclampsia/eclampsia) (4) sepsis (5) others.</p>
<b>Van den Akker et al. (2011)</b>	<p>Uterine rupture: Clinical symptoms or intrauterine foetal death that led to laparotomy at which diagnosis of uterine rupture was confirmed.</p> <p>Eclampsia or severe preeclampsia: Preeclampsia with maternal indication for termination of pregnancy.</p> <p>Obstetric haemorrhage: Transfusion of at least two units of <math>450</math> ml of whole blood or haemoglobin level below <math>6g/dl</math> measured after vaginal bleeding or an estimated blood loss of more than one litre.</p> <p>Severe obstetric and non-obstetric peripartum infection: Infections which required intravenous antibiotics or intravenous anti-malaria or surgical interventions.</p>

### 2.3.5. Methods used to implement the concept of MNM for assessing the quality of care

Five methods were identified to implement MNM audit/review to assess the QoC: (1) surveillance, (2) survey, (3) criterion-based audit, (4) facility-based review, and (5) Confidential Enquiry into Maternal Morbidity (**Table 2.5**). These methods can be used separately or in combination. Survey or surveillance can be combined with criterion-based audit (e.g. the work by Oladapo et al. 2015). Facility review can be conducted along criterion-based review ( e.g Baltag, Filippi and Bacci, 2012) or confidential enquiry such as in the UK system (Knight et al.2014a).

*Table 2.5: Methods used to implement MNM review for assessing the quality of care*

	Method	Definition
1	Surveillance	"A continuous, systematic collection, analysis and interpretation of data". (WHO, 2017)
2	Survey	"A periodic collection of data at a specific time". (WHO, 2017)
3	Criterion-based audit	"A systematic review of care against explicit criteria and target that aims to improve the outcomes". (WHO, 2004)
4	Facility review	An in-depth qualitative review of MNM cases/ medical record at facility level.
5	Confidential Enquiry into Maternal Morbidity	An external anonymous investigation of MNM by an independent expert panel.

#### 2.3.5.1. Survey and surveillance

Surveillance and survey collect quantitative data to measure the frequency of MNM events to estimate the incidence or prevalence of MNM as a proxy for QoC. Over time, these figures can be used for comparison and monitoring. Furthermore, these methods examine the nature of the events by analysing the distribution of the underlying causes of MNM, to identify potentially preventable causes such as obstetric haemorrhage and sepsis (Roost et al., 2009; Almeria et al., 2010; Siddiqui, Soomro and Shabih-UI-Hasani, 2012; David et al., 2014).

The socio-demographic and clinical characteristics of the women are also analysed to identify associated factors and risks for MNM to identify areas of care which can be improved. For instance, Rabia et al. (2011) in India explored the factors associated with severe maternal morbidity and maternal deaths to formulate guidelines to improve the QoC. Soma-Pillay et al. (2015) in South Africa, from their analysis of a survey using hospital data, found that there were missed opportunities for identifying and managing severe complications in women presenting with MNM events because of the weak referral system and an inadequate number of antenatal visits.

In this review, most of the surveillance and survey data were collected from the medical notes of patients. David et al. (2014), Adeoye et al. (2015), and Kiruja et al. (2017) complemented the gap in the medical records by interviewing the women or their relatives to explore the delays in receiving care. Such interviews also explored the women's perceptions and experiences of care they received.

Survey and surveillance were found to be the most commonly applied methods in this review. They were used in 83 (84.7%) of the included articles, and in 12 papers they were used in combination with other methods (Annex 1). Ten papers described surveillance systems in various countries, including the (whole) UK (Knight et al., 2014), Scotland (Marr, Lennox and McFadyen, 2014); Netherlands (van Dillen et al., 2010), Belgium (Vandenberghe et al., 2017), Nigeria (Oladapo et al., 2016), Brazil (Amaral et al., 2011; Haddad et al., 2014; Pacagenella et al., 2014; Cecatti et al., 2015), and India (Bhattacharyya, Srivastava and Knight, 2014). The surveillance systems in the UK, Scotland, and Belgium operate through using a routine mailing system to the focal person in all consultant obstetrician-led units. Overall, these systems operate in obstetrics-led units and tertiary care healthcare facilities. They were used for research and monitoring purposes.

Nonetheless, MNM surveillance and surveys have some notable limitations in assessing QoC. Some studies utilising these approaches have a tendency to focus on collecting MNM events only from obstetric units/departments rather than all potential hospital units/departments where pregnant women are cared for, thereby missing a proportion of cases with severe maternal morbidity, in particular those with non-obstetric complications (Siddiqui et al., 2012; Adeoye et al., 2015).

As described by Almerie et al. (2010), the major limitation of survey and surveillance techniques is their inability to identify the underlying reasons for substandard care. Complementing this approach with criterion-based audit, as Oladapo et al. (2015) did in Nigeria, could overcome this limitation. Data were collected in the time interval between the diagnosis of the severe complication and initiation of the definitive interventions, and the time at which the most senior personnel attended to the women; the resultant data was compared with previously set criteria. This study quantified the magnitude of MNM and identified areas with substandard care.

Surveillance of MNM cases can also be complemented by Confidential Enquiry into Maternal Morbidity. A good example is the UK national surveillance system on near-misses. The UK Obstetric Surveillance System (UKOSS) measured the burden of

severe morbidity, risk factors, and variation in management, seeking to quantify outcomes (Knight et al., 2014). The in-depth qualitative review of medical records of MNM through Confidential Enquiry into Maternal Morbidity enables an understanding of the clinical context of these morbidities and associated factors (Knight et al., 2014).

#### *2.3.5.2. Criterion-based clinical audit*

Criterion-based clinical audit is a systematic review of care against explicit criteria and targets that aims to improve outcomes (WHO, 2004). In this audit, a specific topic which is part of the process of care is audited rather than a broad topic; for example, auditing the use of magnesium sulphate in the management of eclampsia rather than looking at the whole management of eclampsia. To achieve this, the records of patients with eclampsia are reviewed to determine whether they received magnesium sulphate or not, and the proportion of cases where magnesium sulphate was used is calculated and compared to the set target (e.g. 100%) to determine the QoC. This approach was used in 16 papers; 13 of which were based on the WHO approach (Annex 1). Indeed, the WHO near-miss approach (WHO, 2011) is built on the criterion-based audit method, with a core focus on surveying and measuring key interventions for the prevention and treatment of four severe complications: severe pre-eclampsia, eclampsia, severe postpartum haemorrhage, and severe sepsis.

Criterion-based clinical audit is a useful tool for monitoring the coverage of key interventions (Jabir et al., 2013; Bashour et al., 2015), and its findings are useful for designing future quality improvement interventions (Bashour et al., 2015). A number of studies in this review, however, described high mortality and morbidity despite high coverage of key interventions (Jabir et al., 2013; Souza et al., 2013; Bashour et al., 2015; Oladapo et al., 2016). These studies could not explore the reasons for such contradictory findings and recommended further in-depth review of the cases.

#### *2.3.5.3. Facility-based review*

Facility-based review involves a comprehensive review of the case notes, allowing a deeper analysis and understanding of the clinical context of the cases and the factors contributing to the outcomes. The added value of this review compared to criterion-based audit lies in the fact that it allows analysis of all aspects of the care women received, with best clinical practice identified even with unavailability of standards (Knight et al., 2014a). This analysis assists in understanding why the near-miss event occurred and the reasons for substandard care. Six papers were identified describing use of facility-based review (Lawton et al., 2010; van den Akker

et al., 2011; Baltag, Filippi and Bacci, 2012; Nielsen et al., 2013; Bhattacharyya, Srivastava and Knight, 2014; Bacci et al., 2018).

During a facility review, the case is reviewed by a multidisciplinary panel from the same facility where the MNM occurred, although an external expert can be invited to participate (van den Akker et al., 2011; Baltag, Filippi and Bacci, 2012). Substandard care and avoidable factors are identified during the discussion, forming the basis for the proposed actions. In most cases, the benchmark against which the QoC is evaluated is the national or international case management guidelines. Occasionally, women are interviewed before the meeting to learn from their perspective of care and to identify other factors (Baltag, Filippi and Bacci, 2012).

Facility review can improve the QoC as well as maternal outcome. For instance, after initiating such review in Thylo district in Malawi, van den Akker et al. (2011) found that incidence of MNM have declined from 13.5 per 1000 deliveries to 10.4 per 1000 deliveries during the two-year period of implementation.

The major advantages of facility-based reviews are the empowerment and education of the involved staff (van den Akker et al., 2011). They help to strengthen the collegiately between the various departments and cadres of staff involved in the care of pregnant woman (Lawton et al., 2010). Deficiencies in QoC and surrounding factors can be identified and addressed (Baltag, Filippi and Bacci, 2012), and the involvement of stakeholders and administrative authorities can facilitate implementation of recommended actions. On the other hand, such involvement can also inhibit the discussion because of fear of punishment (Baltag, Filippi and Bacci, 2012). The other limitation of this type of review is the risk of bias in addressing issues related to staff (Baltag, Filippi and Bacci, 2012; Lawton et al., 2014). In addition, with a small number of cases, the clinical events cannot be described in detail in a report because of the risk identifying patients and staff (Lawton et al., 2010). To overcome these challenges, facility review can be part of more comprehensive audit and review system in the region of country like the proposed framework for MNM review for India (Bhattacharyya, Srivastava and Knight, 2014).

#### *2.3.5.4. Confidential enquiry into MNM*

Confidential Enquiry into MNM (CEMNM) is an anonymous investigation of all, or a representative sample of, MNM cases at regional or national level. The cases are usually reviewed by one or more multidisciplinary, independent experts to identify causes and associated remediable factors. The advantage of this method compared

to facility review is that it ensures confidentiality by anonymising the details of the women and care providers, thus reducing bias in the review process (Lawton et al., 2014). As the cases are drawn from across the country or region, vignettes can be used in the published report to illustrate the real context of the occurrence of the MNM events (Knight et al., 2014a).

Five papers were identified describing the use of CEMNM to assess the QoC; from the Netherlands, Brazil, New Zealand, and two papers from the UK. The UK has a national system for Confidential Enquiry into Maternal Morbidities based on an annual open topic proposal (Knight et al., 2014a). An independent advisory group selects the topic based on the expected impact of the review in terms of improving the QoC. This review allows for the identification of system related issues, which sometimes need to be addressed at a higher level. Combining the quantitative data from the UK Obstetric Surveillance System (UKOSS) with the qualitative findings from the confidential enquiries provides strong evidence for recommendations for improvement in care. The findings are published along the findings of maternal deaths review.

The Scottish Confidential Audit of Severe Maternal Morbidity (SCASMM) includes surveillance of severe morbidities using standard criteria. Cases with obstetric haemorrhage and eclampsia are subjected to a detailed confidential review of the care provided (Marr, Lennox and McFadyen, 2014). The findings of the review have been used to inform clinical practice by sending feedback to each maternity unit and publishing an annual report. It was noted that such an approach assists in increasing adherence to the clinical guidelines and ultimately improving the QoC (Marr, Lennox and McFadyen, 2014).

In the Netherlands, a national prospective cohort study of severe maternal morbidity was conducted over two years to assess the incidence, risk factors, and substandard care in cases of severe maternal morbidity (van Dillen et al., 2010). The substandard care was assessed through a confidential review of a sample of identified cases (2.6%). The cases were reviewed by a panel to assess the QoC and identify associated factors related to the women, healthcare providers, and health system. The review revealed substandard care in 79% of cases, and highlighted areas for improvements in both the clinical practice and in the health system.

In New Zealand, Lawton et al. (2014) tested the feasibility of introducing a multidisciplinary external expert panel review of cases of severe maternal morbidity

admitted to the intensive care unit (ICU)/ high dependency unit (HDU) in four districts. The panel reviewed the care provided for each of the cases; a consensus was reached on assessing the potential of preventing maternal morbidity using a modified model from Geller et al. (2004). Themes of substandard care were identified during the review process. The review found that around 40% of cases were potentially preventable. For another 37% of cases, although these were classified as not preventable, potential areas of improvement in care were also identified. The review showed that factors related to health providers were the most common identified preventable factors. It was concluded that the review was successful in identifying areas for improvement and therefore it was scaled up nationally.

In Brazil, Amaral et al. (2011) described a collaborative project in the city of Campinas between academia and the Municipal Regional Maternal Mortality Committees. The in-depth review of cases of MNM was integrated into the maternal deaths review. The cases were anonymised and reviewed and by the Municipal Maternal Mortality Committee who assigned a preventability score and identified substandard care and contributory factors. It was found that such a review and analysis of the chain of events that led to severe morbidity and mortality motivated a learning process among the committee members. Furthermore, the review of MNM expanded the understanding of the spectrum of morbidity to mortality among committee members.

From the above examples, it can be seen that one of the challenges of conducting CEMNM is that it requires resources to collect and anonymise the records of eligible cases and to coordinate the review process. The other limitation of this review could miss contributing factors related to women and healthcare system, such as shortage of staff if the review depends only on using clinical notes. **Table 2.6** summarises the strengths and limitations of the above described methods.

Table 2.6: Methods used to implement MNM review for assessing the QoC

	Description	Mechanism of evaluating QoC	Strengths	Limitations
<b>Survey/ surveillance</b>	Systematic collection, analysis, and interpretation of quantitative data	Measuring the burden/ frequency of MNM (incidence, prevalence) as a proxy for QoC	Estimate incidence/ prevalence. Can be used for monitoring/ comparison Describes the characteristics of the cases Describes the causes and risk factors Quantifies the outcomes	Identifying the area of substandard care and reasons for poor quality of care
<b>Criterion-based audit</b>	Systematic review of care against explicit criteria and target	Assessing the process of care by comparing the care provided with explicit criteria and standards of care	Identifies gaps in adherence to protocol/ standards Facilitates monitoring of implementation of standards	Focus on specific aspect/s of care Inability to identify reasons for non-adherence to the standards
<b>Facility review</b>	In-depth review of cases by a panel from the same facility where cases occurred	Assessing the potential of preventing severe complications Assessing contributing factors Assessing clinical context	Comprehensive review of cases Considers the clinical context Identifies local associated factors Deficiencies in the QoC can be identified and addressed locally Empowerment and educational exercise for the involved staff	Risk of identifying staff involved in providing care with subsequent risk of punitive measures Risk of identifying and sharing confidential data More risk of less objective analysis of QoC
<b>Confidential enquiry</b>	Anonymous investigation of all, or a representative sample of, MNM cases at regional or national level by external expert(s)	Assessing the potential of preventing severe complications Assessing contributing factors Assessing clinical context	Comprehensive review of cases Less bias in identifying the substandard care Able to make general recommendations at regional or national level Identifies areas that need to be addressed at the high policy level	Risk of focusing on clinical aspect only and missing factors related to woman and treating facility Extensive resources are needed; could be expensive and time consuming

### 2.3.6. Indicators used to measure QoC using MNM concept

94 out of 98 included articles reported using indicators to assess the QoC using MNM. These indicators can be divided into two groups: those recommended by WHO, and those using other indicators (**Table 2.7**).

*Table 2.7: Indicators measuring QoC*

Indicator	Definition
<b>WHO proposed outcome indicators</b>	
1. MNM mortality ratio	The number of MNM cases per 1,000 live births
2. Severe maternal outcome ratio (SMO)	Total number of maternal deaths and MNM per 1000 live births
3. MNM mortality ratio (MNMR)	The ratio between MNM and maternal deaths
4. Mortality index (MI)	The ratio between MNM and maternal deaths
5. Perinatal outcome	Indicators related to foetal and neonatal outcomes (e.g. perinatal mortality, neonatal mortality, stillbirth rates)
<b>WHO proposed process indicators</b>	
1. Coverage of key interventions	Percentage of women receiving key interventions for prevention and management of the most common obstetric complications from target women
2. Intra-hospital and hospital access indicators	Measured the proportion of women who presented with near-miss event or deaths within 12 hours or after hours from the total number of cases involving life-threatening conditions.
3. Intensive care use	Measured the availability of and use of ICU in the management MNM
<b>Other indicators</b>	
1. Incidence of MNM	Total number of new cases of MNM divided by the target population (total maternity cases or deliveries)
2. Prevalence of MNM	Total new and old cases of MNM divided by the target population (total maternity cases or deliveries)
3. Preventability score	Score allocated during in-depth review of MNM or deaths to actions or factors that could accelerate the deterioration of the medical condition to the severe morbidity or death
4. Maternal severity index	Estimation of probability of maternal death using maternal severity score to assess the performance of the health system in managing life-threatening conditions Souza et al.2012).

The indicators proposed by WHO are subdivided into outcome and process indicators. The following sub-sections present the studies reporting these indicators, summarised in **Annex 2**.

#### 2.3.6.1. The proposed WHO MNM outcome indicators

- *Maternal near-miss ratio*

Although the WHO defines the MNM ratio as the number of MNM cases per 1,000 live births, the review reveals that this indicator was used interchangeably with incidence, prevalence, and rate (Oliveira Neto et al., 2009; Siddiqui, Soomro and Shabih-UI-Hasani, 2012; Tunclap et al., 2012; Nadari et al., 2015). For example, in a systematic review the prevalence of MNM was estimated for each identification

criteria by pooling data from studies applying the same criteria without considering what these studies are reporting: prevalence, incidence, or ratio (Tunclap et al., 2012). Secondly, the authors described five studies that used live births as the denominator in their calculation, which means that these studies reported ratio, not prevalence, yet these studies were not treated separately. Similarly, a number of studies, despite calculating the MNM ratio, tended to treat this ratio as a rate in their report and comparison (Siddiqui, Soomro and Shabih-UI-Hasani, 2012; Nadari et al., 2015). For example, Siddiqui, Soomro and Shabih-UI-Hasani (2012) reported that they found an MNM of 79.97 per 1,000 live births, but in their discussion referred to the same figure as a rate and compared this with the rate previously reported in the literature. In strict epidemiology, there is a distinction between ratio, rate, incidence, and prevalence (**Table 2.8**).

*Table 2.8: Definitions of ratio, rate, incidence and prevalence*

Indicator	Definition
<b>Ratio</b>	A relationship between a numerator and a denominator, which are usually distinct and not derived from the same population. It often compares two rates
<b>Rate</b>	A measure of the frequency of occurrence of event/condition in a defined population in defined time
<b>Incidence</b>	A measure of the occurrence of new cases in a defined population
<b>Prevalence</b>	A measure of frequency of new and old cases with specific condition in a defined population

Source: (Gerstman, 1998; Aschenhrau and Seag, 2013)

### **MNM ratio by identification criteria**

The MNM ratio was reported by 58 studies out of 94, with the majority of these being based on WHO's near-miss approach, using live births as a denominator. Two studies reported using births as a denominator; one was based on mixed criteria from the Netherlands (van Dillen et al., 2010), and one based on organ dysfunction criteria from Scotland. .

Study-specific ratios varied based on identification criteria. In general, in all categories, there was a wide range in the reported ratio (**Annex 2**). For example, of 16 studies using disease-specific criteria, six reported the MNM ratio, which ranged between 10.5 to 50.0 per 1000 live births (Roost et al., 2009; Almerie et al., 2010; Ali et al., 2011; David et al., 2014; Naz et al., 2014). Siddiqui, Soomro and Shabih-UI-Hasani (2012) reported a higher ratio from a tertiary public hospital in Pakistan of 76.96 per 1000 live births. This figure could be accurate for the context where the study took place, since the hospital caters for a high number of patients from low socioeconomic class, and the majority of recruited women were un-booked for

antenatal care, putting them at higher risk of developing severe complications (Siddiqui, Soomro and Shabih-UI-Hasani, 2012). Similarly, 44 out of 58 studies which applied the WHO criteria reported the MNM ratio and recorded a wide range.

In the group using mixed criteria, five out of eleven studies reported MNM ratio. In the category of management-based criteria, only Karolinski et al. (2010) measured the MNM ratio from a study in Argentina and Uruguay (3.4 per 1000 live births). The study was nested research in a randomised trial for guidelines that excluded abortion cases, which could affect the obtained ratio. Similarly, among the group of organ dysfunction, only one paper was identified, reporting an MNM ratio of 6.1 per 1000 births from the Scotland confidential Audit of Severe Maternal Morbidity (Marr, Lennox and McFadyen, 2014).

- *Severe maternal outcome ratio (SMOR)*

The SMOR was reported by 37/94 studies, all based on the WHO approach, except for two studies: one using disease-specific criteria (David et al., 2014) and one from the organ dysfunction group (Chaudhuri and Nath, 2018). They recorded ratios of 22.7 and 49 per 1,000 live births (respectively). Similar to the MNM ratio, there was a wide variation in the reported ratio from the studies based on the WHO approach as described in **(Annex 2)**.

- *MNM mortality ratio (MNM: 1MD)*

MNM mortality ratio (MNM: 1MD) refers to the ratio between MNM and maternal deaths, whereby a higher ratio indicates that more women survive, thus indicating better QoC (WHO, 2011). This ratio was reported by 36 out of 94 studies, mostly by those using WHO criteria. The studies that used the whole criteria (16) recorded a ratio ranging between 2.5: 1 (Mazhar et al., 2015) in Pakistan to 58: 1 in Tunisia (El Ghardallou et al., 2016). Nadari et al. (2015) recorded a higher ratio of 250: 1 from eight hospitals in Iran (250:1).

From the disease-specific criteria group, six studies reported a ratio between 3.5:1 to 60.1:1 (Annex 2). Retrospective analysis of the Médecins Sans Frontières (MSF) database from five countries in sub-Saharan Africa yielded a ratio of 100:1 (Tamura et al., 2012). However, this figure is questionable as 36% of deaths were excluded from the calculation because they were classified under “other complications”.

Among the management-based criteria group, the reported figure was 8.5:1 from Italy (Donati, Senatore and Ronconi, 2012) and 37.4:1 from Brazil (Oliveira Neto et al., 2009). Two studies using organ dysfunction group reported an MNM: 1MD ratio

of 79:1 from Ireland (Murphy et al., 2009) and 7.7:1 from India (Chaudhuri and Nath, 2018). Two studies also from the mixed criteria group reported a ratio of 23.7:1 from Brazil (Amaral et al., 2011) and 15:1 from Argentina (Karolinski et al., 2013).

- *Mortality Index*

The Mortality index (MI) is calculated similar to case fatality rate (CFR) by dividing the number of maternal deaths by the total number of maternal deaths plus MNM (MD/MD + MNM). A higher index indicates that more women with severe complications die, thus reflecting poor QoC (WHO, 2011).

This indicator is the least reported outcome indicator found in this review, being reported in 23 out of 94 studies, and three studies used CFR. Among the disease-specific group, three studies measured it, and there was a wide range in the reported figures. Among the management-based criteria group, Chantry et al. (2015) in France and Karolinski et al. (2010) in Argentina and Uruguay used CFR (1.3% and 13% respectively). Karolinski et al. (2013) using mixed criteria to report a CFR of 6.2% from 25 hospitals in Argentina. None of the studies using the organ dysfunction criteria measured the MI or CFR. From the WHO criteria group, 14 studies measured the MI, which ranged between 0.2% and 29.1. Among the group that used modified WHO criteria, seven studies reported the MI index, ranging between 0.3% to 40.8%.

Studies recorded a variation in MI and MNM: 1MD per specific causes of MNM. Although obstetric haemorrhage and hypertensive disorders were the most commonly identified causes of MNM, they have better outcomes compared to other causes. For example, Oliveira Neto et al. (2009) in Brazil found that hypertensive disorders accounted for 72.7% of MNM cases, followed by haemorrhage (20.8%) and infections (3.8%). However, the MNM: 1MD was 6:1 for infection, compared to 30:1 for haemorrhage and 322: 1 for hypertensive disorder, respectively. Ali et al. (2011) in Sudan and Almerie et al. (2010) in Syria observed that the highest MI was for infection (22.2% and 7.4%), and the lowest was for hypertensive disorder (2.4% and 0.4%). Like sepsis, non-obstetric causes such as embolism have a lower survival rate (Oliveira Neto et al., 2009; Oladapo et al., 2015).

Another observation worth noting is that some studies faced challenges in using MI and MNM: 1MD as indicators for QoC. Almerie et al. (2010) in Syria argued that while MI is useful in assessing the effectiveness of management in MNM, it is limited in identifying the reasons behind poor QoC. Jayaratnam et al. (2016) emphasised

that caution needs to be taken in the interpretation of these indicators as proxies of QoC, especially in settings with a low number of maternal deaths. They observed an unexpected MNM: 1MD ratio of 10: 1 in a high resource hospital in Australia. In another hospital with no recorded maternal deaths, Jayaratnam et al. (2018) faced a challenge in using these indicators as QoC indicators.

- *Perinatal outcome*

The WHO (2011) recommended measuring perinatal outcome indicators to complement MNM quality indicators, but only 13 out of 94 studies did so. These studies examined perinatal outcome-related stillbirths (SB) (n = 9), low birth weight (LBW <2.5 kg) (n = 5), perinatal death (n = 4), preterm delivery (n = 4), birth asphyxia (n = 4), and early neonatal death (n = ENND) (n = 1). They recorded a high rate of stillbirths and early neonatal deaths among MNM cases (**Table 2.9**).

Table 2.9: Perinatal outcome indications among MNM

Study	MNM criteria	% of MNM with SB	Perinatal death (%)	ENND (%)	LBW (%)	Asphyxia (%)	Preterm delivery (%)
Adeoye, Onayade and Fatusi (2013)	Disease-specific	22.0	-	-	44.4	22.2	41.4
Adeoye, Onayade and Fatusi (2015)	Disease-specific	27.0			44.4	22.2	
Ali et al. (2011)	Disease-specific	23.7	-	5.9%(NND)	-	-	-
Almerie et al. (2010)	Disease-specific	6.0					
David et al. (2014)	Disease-specific	29.9	33.8	-	-	-	-
Ghazal Aswad et al. (2013)	Disease-specific	-	4.7	-	-	-	-
Gombar, Ahuja and Jafra (2014)	Management-based	21.2	-	-	-	-	
Jabir et al. (2013)	WHO	20.0	43.8	-	-	-	36.5
Lotufo et al. (2012)*	WHO	17.5	21.2	-	48.4	25.0	31.2
Madeiro et al. (2015)*	WHO	-	-	-	50.0	Low Apgar 26.4	54.8
Panda et al. (2018)	WHO	7.9	-	-	49.9	-	-
Soma-Pillay et al., 2015	WHO	-	19.6	-	-	-	-

\*Figures for MNM and maternal deaths

### 2.3.6.2. The proposed WHO process indicators

Thaddeus and Maine (1994) published a conceptual framework on factors that affect the interval between the onset of maternal complications and severe outcomes such as MNM and death, called “Three Delays Model” (**Figure 2.5**).

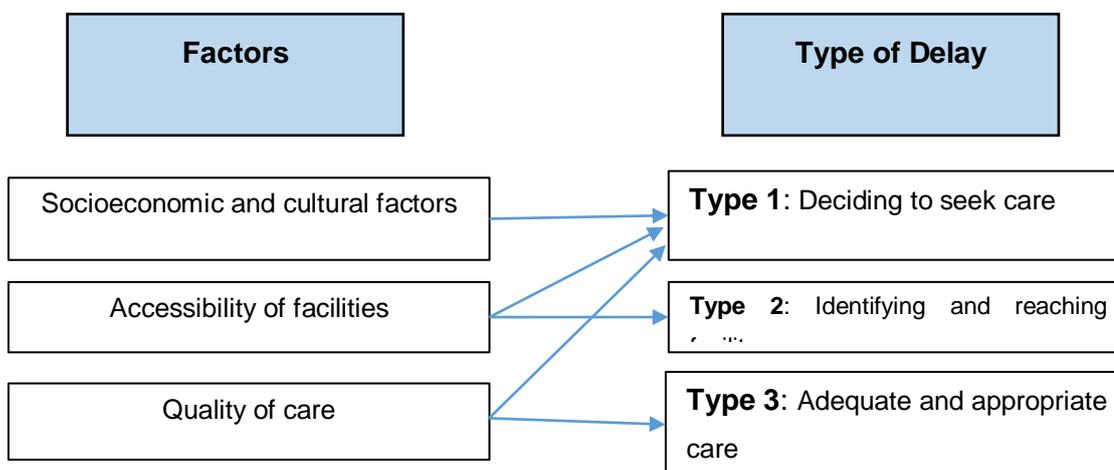


Figure 2.5: Three delays model

The process indicators proposed by WHO attempt to examine these delays, specifically two and three. These indicators include: (1) coverage of key interventions, (2) intrahospital care, (3) hospital access to care, and (4) intensive care use.

- *Coverage of key interventions*

A list of process indicators was suggested in the WHO MNM approach for assessing the use of key interventions, with the assumption that such indicators can highlight the gap between the actual and recommended use and thereby help to assess the QoC. These interventions target the prevention and management of most common obstetric conditions (**Table 2.10**) (WHO, 2011). These indicators have been measured in 14 out of 94 studies (Karolinsk et al. (2010), Ashma, Gehanath and Ganesh, 2013; Jabir et al., 2013; Nelissen et al., 2013a; Souza et al., 2013; Tuncalp et al., 2013; Haddad et al., 2014; Mazhar et al., 2015; Oladapo et al., 2015; Kalisa et al., 2016; Norhyati et al., 2016; Herklots et al., 2017; Sayinzoga et al., 2017; Woldeyes, Asefa and Muleta, 2018). All of these studies were based on the WHO approach expect Karolinsk et al. (2010), which used management-based criteria. Some studies noted an unacceptable coverage of these interventions. For example, Tuncalp et al. (2013) observed that only 62.0% of women in Ghana who developed postpartum haemorrhage received oxytocin, and less than half (41%) of those with sepsis received parenteral treatment. Nelissen et al. (2013a) in Tanzania found that

among women who underwent a caesarean section, only 66% received prophylactic antibiotics. Kalisa et al. (2016) in Rwanda observed suboptimal administration of oxytocin to 74.4% of women with severe haemorrhage and parental antibiotic to 47.4% of those with sepsis.

*Table 2.10: WHO proposed indicators for coverage of key interventions*

Condition	Indicator
<b>Prevention of postpartum haemorrhage</b>	Number of women who received a single dose of oxytocin for the prevention of postpartum haemorrhage divided by the number of all women giving birth (vaginal delivery + caesarean section)
<b>Treatment of postpartum haemorrhage</b>	Number of women with postpartum haemorrhage who received therapeutic oxytocin divided by the number of all women with postpartum haemorrhage
<b>Eclampsia</b>	Number of women with eclampsia who received magnesium sulphate divided by the number of all women with eclampsia
<b>Prevention of severe systemic infections or sepsis</b>	The number of women having a caesarean section and receiving prophylactic antibiotics divided by the number of all women having caesarean sections
<b>Treatment of severe infections and sepsis</b>	The number of women with severe systemic infections or sepsis who received antibiotics divided by the number of all women with severe systemic infections or sepsis
<b>Foetal lung maturation</b>	The number of women having a live birth after three hours of hospital stay and receiving corticosteroids for foetal lung maturation divided by all women having a live birth after three hours of hospital stay

Similarly, Karolinski et al. (2010), in their review of the use of the evidence-based practice in Argentina and Uruguay, reported that the overall use rate of effective interventions was only 58% among cases of maternal deaths and near-miss. These studies suggested that high mortality and morbidity were due to the low coverage of such key interventions.

Conversely, several studies described a high coverage rate of key interventions, despite observing a high rate of mortality and severe morbidities (Ashma, Gehanath and Ganesh, 2013; Souza et al., 2013; Tuncalp et al., 2013; David et al., 2014; Bashour et al., 2015; Oladapo et al., 2015). For example, Bashour et al. (2015) in their study in Egypt, Lebanon, Palestine, and Syria noted a high MI despite a high coverage of key interventions. Likewise, the results of the WHO Multicounty Survey in 29 countries showed high mortality in some facilities, despite a high coverage of key interventions (Souza et al., 2013). The study concluded that high coverage of these interventions did not necessarily reduce maternal mortality. Delays or poor implementation of these interventions was proposed as an explanation for this observation, and it was recommended that an in-depth review of these cases was required.

Oladapo et al. (2016) offered a more in-depth investigation in their Nigerian context by measuring the time taken to initiate these key interventions and the attendance of senior health personnel to women with life-threatening conditions. They found that in the majority of these cases women received the key interventions to avert death, but there was a substantial delay in many of them. The median time between the diagnosis of a life-threatening condition and the initiation of critical intervention was about an hour. In about a quarter of cases, the delay was for more than four hours. A similar finding was observed regarding the involvement of senior cadre in care of these severe cases.

David et al. (2014) in their study in Mozambique also reported that third type of delay contributed significantly to MNM and maternal deaths. About 70% of the MNM cases experienced type three delay. In more than 25% of MNM cases, the initial treatment was initiated within half an hour of arrival. Lack of blood products in the healthcare facility contributed to 35% of the MNM cases, and unavailable operating theatres to 42.0%.

- *Intra-hospital and hospital access indicators*

To assess type two delay, the WHO suggested the segregation of MNM cases on arrival from those who developed severe events in hospital and measuring two sets of indicators: hospital access and intra-hospital indicators (WHO, 2011). The former measure failure in accessing care or weakness in the referral system, while the later reflect the QoC in the healthcare facility (**Table 2.11**).

*Table 2.11: Intrahospital and access indicators*

<b>Hospital access indicators</b>
1. SMO cases presenting the organ dysfunction or maternal death within 12 hours of hospital stay (SM012) (number)
2. The proportion of SM012 cases among all SMO cases
3. The proportion of SM012 cases coming from other health facilities
4. SM012 mortality index
<b>Intrahospital care</b>
1. Intrahospital SMO cases (number)
2. Intrahospital SMO rate (per 1000 live births)
3. Intrahospital mortality index

The hospital access indicators measured the proportion of and SMOR ratio in addition to MI for women presenting with near-miss events or who died within twelve hours of the initial life-threatening condition, whereas the intra-hospital indicators focused on the first twelve hours from admission. In this review, only five studies applied these recommended indicators (Jabir et al., 2013; Tuncalp et al., 2013;

Herklots et al., 2017; Saynizoga et al., 2017; Woldeyes, Asefa and Muleta, 2018). Jabir et al. (2013) reported that two-thirds of women in Iraq who had SMO within the first twelve hours of admission were admitted without referrals, which might indicate weaknesses in the referral system and/ or delay in accessing appropriate care. Nonetheless, the MI for both the referred and in-patient groups were almost the same. Tuncalp et al. (2013) recorded that 80% of women in a tertiary care hospital in Ghana who had a severe maternal outcome in the first twelve hours had been referred from lower-level facilities. Nonetheless, the MI was higher for those who developed the severe complications in the hospital (16.4% versus 41.1%). Sangeeta et al. (2015) in North India measured only the intrahospital MI, which was 14.2%.

Failure to access the healthcare facility can be due to a delay in the decision to seek care (first type of delay) or delay in reaching the facility (second type of delay). The hospital access indicators do not segregate these types of delays. As illustrated in **Figure 2.5**, the QoC can also affect the decision to access care. 13 studies therefore assessed the accessibility of services and the QoC by measuring the proportion of MNM and maternal deaths to the appropriate healthcare level and then exploring reasons for the delay (Roost et al., 2009; Adeoye, Onayade and Fatusi, 2013; Ashma, Gehanath and Ganesh, 2013; David et al., 2014; Litorp et al., 2014; Naz et al., 2014; Pacagenella et al., 2014; Oladapo et al., 2015; Soma-Pillay et al., 2015; Kulkarni et al., 2016; Yadav and Nada, 2016; Kiruja et al., 2017; Iwuh et al., 2018; Woldeyes et al., 2018).

Oladapo et al. (2016) in Nigeria, found that (91.8%) of MNM and maternal deaths occurred before arrival to tertiary hospitals. Similarly, a high percentage of delay was reported from Tanzania (87%), Bolivia (74%), Nepal (> 50%), Pakistan (>50%) and Brazil (34.6%), which was in each case attributed to weak referral systems (Roost et al., 2009; Ashma, Gehanath and Ganesh, 2013; Litorp et al., 2014; Naz et al., 2014; Pacagenella et al., 2014). In addition, poor knowledge about complications, a lack of previous experience with the healthcare system, perceived QoC, and unavailability of emergency obstetric care in the accessible facility were contributing factors to the late presentation of MNM cases (Adeoye, Onayade and Fatusi, 2013; David et al., 2014; Assarag et al., 2015).

Furthermore, a number of studies also further explored the delay at the hospitals (Lawton et al., 2010; van Dillan et al., 2010; Lawton et al., 2014; Pacagenella et al., 2014; Oladapo et al., 2016; Ozimek et al., 2016; Woldeyes et al., 2018). In their analysis these studies broadly divided the identified factors into three categories,

related to patients, healthcare systems, and the treating healthcare team. These studies found that providers related factors were the most frequent identified factors. For example, Ozimek et al. (2016) recorded healthcare provider-related factors in 78.8% of women with severe maternal morbidity.

- *ICU use*

The WHO MNM approach included four indicators related to ICU use (WHO, 2011). The first two measured the availability of ICU beds by calculating overall ICU admission rate and ICU admission among women with SMO. The third indicator is the SMO rate among women admitted to an ICU, which assesses the optimum use of ICU beds. The last indicator is the proportion of maternal deaths without ICU admission, which could reflect a shortage of ICU beds if it is high.

Apart from studies using ICU admission as identification criteria, 15 other studies examined the rate of admission of SMO cases to an ICU (Annex 1.),

These studies reported a variation in the percentage of MNM admitted to ICU **Annex 1**. In general, it seems that the ICU utilisation rate for women with SMO is low in poor resource countries compared to the proposed WHO rate of 70%. For example, in Ghana, only 19.1% of SMO cases admitted to an ICU. (Tuncalp et al., 2013). Similarly, in Pakistan, intensive-care facilities were available for only for 32.6% of women with SMO (Mazhar et al., 2015). Conversely, in the United Arab Emirates (UAE) almost 60.0% of women with SMO were admitted to an ICU (Ghazal-Aswad et al., 2013), and in Tunisia 70.0% of MNM cases had ICU admission.

However, it is important to note that the range of intensive care services varies across different settings from HDU to ICU, as well as the selection of the severity of cases to be admitted, both of which could affect the comparison of the ICU admission rate (Chantry et al., 2015).

#### *2.3.6.3. Incidence and prevalence of MNM*

19 out of 94 studies measured incidence of MNM. The studies using ICU admission tended to use rate of obstetric admission per 1000 deliveries to present the incidence of obstetric ICU admission as a proxy for the frequency of occurrence of MNM in the facility (Oliveira Neto et al., 2009; Gombar, Ahuja and Jafra, 2010; Aldawood et al., 2011; Donati, Senatore and Ronconi, 2012; Mansoor et al., 2014; Chantry et al., 2015).

Two studies reported prevalence of MNM. The systematic review by Tuncalp et al. (2012) and the study by Ghazai-Aswad et al. (2013) of disease-specific criteria reported a prevalence of 7.6 per 1000 deliveries from the UAE.

#### *2.3.6.4. Maternal severity index and maternal severity score*

Three studies used the maternal severity index (MSI) indicators (Souza et al., 2012, 2014; Haddad et al., 2014). The MSI tool is used to estimate the probability of maternal death using the maternal severity score to assess the performance of the health system in managing life-threatening conditions. The MSI was developed by Souza et al. (2012) in Brazil using binary regression, it was later validated in the WHO Multicounty Survey where it showed good accuracy in predicting maternal death in women with markers of organ dysfunction (Souza et al., 2013). Measuring MSI involves sophisticated statistical calculation and modelling using the predictors of maternal deaths (such as obstetric and demographic variables, direct and indirect causes of maternal deaths) and life-threatening conditions.

Haddad et al. (2014) argued that MSI is more useful in the context of a population that received care, rather than in assessing a healthcare facility that provides care. They based their argument on the fact that the progression of a woman's condition to the severe outcome does not solely depend on the healthcare facility's role, since the characteristics of the woman and access to care are known factors that affect the likelihood of a severe outcome. If a woman developed a complication and presented late to the healthcare facility in a critical condition, she is more likely to die; such a death cannot be attributed only to the care she received in the facility. Furthermore, from their work in Brazil, they observed that MSI is limited and less precise for use in a population with no observed death or with a small number of cases of life-threatening conditions.

#### *2.3.6.5. Preventability score and opportunity for improvement*

The assessment of preventability has been used in the MNM review to assess the QoC by measuring the percentage of women whose progression to severe morbidity was deemed preventable. Preventability is defined as any action/ inaction taken by a health provider, health system, or woman herself that could accelerate the deterioration of the medical condition to severe morbidity or death (Lawton et al., 2014). This assessment was conducted by allocating a score to these actions or factors during the in-depth review process of the care provided. This score was called the preventability score. Three articles reported the use of the preventability score; Amaral et al. (2011) in Brazil, and Lawton et al. (2010, 2014) in New Zealand.

In New Zealand, a preventability score using the modified Geller model (Geller et al., 2004) was used to review the QoC for MNM admitted to ICU (Lawton et al., 2010, 2014). The Geller model is based on a set of criteria of preventable factors that describe the events from the point of entry to discharge from maternity care (Geller et al., 2004). At end of each review, the reviewed cases were divided into “potentially preventable”, “not preventable but need improvement in care” and “not preventable”. The use of the preventability score was first piloted in one district using a facility-based review (Lawton et al., 2010), and then in four districts using CEMNM (Lawton et al., 2014). The results showed that the tool is useful in diagnosing the areas that required improvements, and hence it was expanded as a national audit system in New Zealand.

Amaral et al. (2011) described the use of the preventability score by the Municipal Maternal Mortality Committee in Brazil to assess substandard care for adverse perinatal events, including MNM. During the review process, the preventable events and related missed interventions were identified. A score from (0) to (5) was allocated for each event, based on a consensus-driven assessment of the capacity of each intervention to prevent the severe outcome. The total preventability score was calculated based on the total number of cases in which a preventable event was suggested.

In the Netherlands, van Dillen et al. (2010) described the use of a scoring system in the process of CEMNM. Each reviewer was requested to score the substandard care and related factors using 15 items. The final score was based on the consensus of the panel discussing the case.

Ozimek et al. (2016) in the United States of America (USA) used term “opportunity for improvement” to categorise the QoC provided to women with severe morbidity. The cases were reviewed by a multidisciplinary panel. At the end of the case review the panel reached consensus on whether opportunity for improvement existed or not. If opportunity for improvement existed, it was categorised as either “possible” or “strong”.

## **2.4. Summary and discussion of the main findings**

### **2.4.1. Definition of and criteria for identification of MNM**

Although different terminologies were used to describe MNM, the majority of studies defined it in terms of a woman who nearly died but survived a complication. Even

with the release of the WHO (2009) criteria, the use of different types of criteria still persist in about 45% of included articles. Within those studies used the WHO criteria, some studies from LMIC reported a challenge in applying the WHO criteria due to a lack of required resources, such as laboratory services, forcing them to use a modified version of the criteria.

In fact, there is an on-going debate in the literature about the sensitivity and applicability of WHO criteria in different settings. For instance, the Brazilian Network for Surveillance of Severe Maternal Morbidity Group found a high association between WHO criteria and maternal deaths, they concluded that WHO criteria enabled them to accurately classify MNM cases (Souza et al., 2012). This finding was supported by the observations of Halder, Joes and Vijayselvi (2014) in a retrospective application of the WHO criteria on maternal deaths in India, where all maternal deaths had at least one organ failure. Similarly, Menezes et al. (2015) in two reference hospitals in Brazil, compared the WHO criteria with Waterstone's or other literature-based criteria, and concluded that the WHO criteria more accurately detected the severe cases. However, this comparison and conclusion is questionable, as the authors considered the WHO criteria to be the gold standard criteria in their comparison (*a priori*).

On the other hand, similar to the findings in this review, a number of studies reported that the WHO organ dysfunction criteria identified only a small proportion of and underestimated MNM. In Brazil, Morse et al. (2011) reported that WHO criteria showed a very high detection threshold, but missing a significant number of MNM cases, in particular severe-preeclampsia and eclampsia cases. In Malawi the WHO organ dysfunction criteria detected only 22% of MNM cases, compared to 46% and 88% identified by the management criteria and by the locally modified criteria respectively (van den Akker et al., 2013). Similarly, in Tanzania, Nelissen et al. (2013b) reported that WHO criteria detected only 60 cases of MNM out of 216 cases identified by the locally modified criteria. The clinical criteria were more sensitive (100%) in identifying the MNM cases compared to management (50%) and laboratory criteria (25%). Such studies concluded that the use of WHO criteria based on organ dysfunction led to the under-reporting of MNM because sophisticated resources are required to fully apply the criteria.

Another observation found in this review is that the use of the WHO criteria is more common in LMIC countries than in high-income countries. HIC countries have a different context; thus, the unavailability of resources cannot be used as an

explanation for the relative reluctance to use the WHO criteria in these countries. Overall, however, it is difficult to generalise these observations, since the review did not focus on examining the use of the criteria *per se*, and articles comparing different criteria were excluded.

Nonetheless, it is notable that Witteveen et al. (2016) in the Netherlands found that the WHO criteria failed to identify two-thirds of cases who had severe life-threatening conditions. Furthermore, Witteveen et al. (2017) analysed and applied the WHO criteria on data from three cohort studies, from the Netherlands (n = 2538), Malawi (n = 386), and Tanzania (n = 248). They concluded that the use of WHO organ failure criteria underestimates MNM, and the criteria do not comprise a useful tool in comparison between different settings. It was concluded in all these studies that clinical criteria or the use of disease-specific criteria are likely to minimise or eliminate this underestimation of MNM (Nelissen et al, 2013b; van den Akker et al., 2013; Witteveen et al.,2016). It has since been recommended that the list of potentially life-threatening conditions in the WHO tool be expanded to capture more severe morbidity cases.

#### **2.4.2. Methods to assess the QoC**

The review revealed that the methods used to implement MNM review or audit to assess the QoC are survey, surveillance, criterion-based audit, facility review, and confidential enquiry. Surveys and surveillance collect qualitative data to estimate burden of MNM as a proxy of QoC. They are useful for monitoring trends and exploring underlying causes. They were the most commonly used methods found in this review. This could be because the most included articles were CSS studies and they tend to be less expensive compare to other approach. Such high use could be because these methods are considered to be the most appropriate methods to measure the incidence and other indicators as well to study the characteristics of affected participants (Mann, 2003). Secondly, they could measure the variation in the management and outcome across facilities (Knight et al., 2014a). They are limited, however, in respect to their ability to explore the reasons for substandard care if used alone.

Criterion-based audit was the second most common identified method. It assesses the process of the care against explicit targets. The studies used this approach were able to identify gaps in application of standards and coverage of essential interventions. However, when substandard or low coverage were observed, these studies were challenge in identifying the reasons.

With in-depth review of the whole or sample of identified cases, facility review and CEMNM were better able to identify factors associated with severe morbidity, diagnose the reasons behind substandard care, and extract lessons to be learnt for future improvements.

Depending on the study aim, one may use each of these methods alone or in combination. It seems using them in combination reduces their individual limitations and provides more comprehensive results that better reflect QoC. Countries implementing a national MNM review system, such as the UK, combined two methods to have a better understanding of QoC and services provided (Knight et al., 2014a).

### **2.4.3. Indicators related to MNM to assess the QoC**

QoC has been assessed using two groups of indicators: the indicators proposed by WHO, and other indicators. Most of the included studies used one or more of the WHO indicators. This could be because around half of the included articles studies are based on the WHO approach. It seems that the ability to measure WHO recommended indicators is not restricted by the case identification criteria, but the studies using non-WHO criteria used these indicators less in comparison.

Similar to the challenges faced by previous systematic reviews, the variation in the identification criteria made it difficult to compare and pool data together from different studies (Say, Pattinson and Gulmezoglu, 2004; Tuncalp, et al.,2012). In addition, there was a wide range in the reported figures across all indicators within the same criteria.

Studies that used recommended WHO indicators tended to measure outcome indicators more than process indicators, with MNM ratio being the most commonly measured indicator. However, as described earlier, a number of studies mixed up this ratio with incidence, prevalence and rate, despite the fact in epidemiology there is a distinction between these indicators (Gerstman, 1998; Aschenhrau and Seag, 2013).

Indeed, using incidence or prevalence is more appropriate than the MNM ratio in measuring the burden of MNM itself. Having maternities or total deliveries as a dominator represents a figure closer to the actual number of women at risk (Knight et al., 2014b). In LMIC, where it could be challenging to measure all pregnancies, the MNM ratio can be accepted as a proxy for the burden of MNM. In these countries it seems to be more appropriate to use total births as the denominator, as

using live births excludes pregnancies that ended in stillbirth. These countries suffer from a high burden of stillbirths and using live births would lead to inaccurate estimation (Aminu et al., 2014).

Although the WHO recommended the indicators relating MNM to maternal deaths (MI and MNM: 1MD ratio) to be used as proxy for the QoC, they were not commonly used, and were reported by less than half of studies. It was shown that these indicators are influenced by a number of factors. The nature of conditions encountered at the healthcare facility might affect the obtained results. As presented earlier, there is a variation in the survival rate between MNM cases with different underlying causes. Non-obstetric complications for example have a lower survival rate than obstetric haemorrhage and hypertensive disorders. Women might present late in critical conditions to healthcare facility with very limited care provided in such scenarios (Jayaratnam et al., 2018).

Additionally, the indicators cannot be used in facilities with no observed maternal deaths; the absence of death in a facility is not necessarily an indicator of good QoC. For instance, women might survive severe obstetric complications but might sustain a long-term disability and disruption to their entire life as a result of receiving poor QoC (Storeng et al., 2010; Assarag et al., 2015). Also, as Filippi et al. (2004) argued, even a low incidence of MNM after admission in healthcare facilities needs to be interpreted with caution when assessing the QoC. Low incidence could be due to the selection of cases to be admitted, with more severe complications being referred to other hospitals immediately without admission. Interpretations of these indicators, therefore, require an understanding of the local context in which these facilities operate.

The process indicators measuring the coverage of key interventions could highlight the utilisation of these interventions. However, they are limited in assessing the actual implementation of these interventions. Assessment of QoC should be more comprehensive, to include the efficiency and timely use of these interventions. As Cecatti et al. (2015) and Haddad et al. (2014) argued, severe maternal morbidities can occur at the same rate, irrespective of the country income. What is most critical is to understand when and how these morbidities occur, if they are managed at the right time, and their consequences are.

Therefore, it seems that the most appropriate indicators to measure the preventability of severe complications or opportunities for improvement in QoC are

those described by van Dillan et al. (2010), Lawton et al. (2010, 2014), and Ozimek et al. (2016). This is because they are based on more comprehensive, in-depth assessment of care provided, similar to the system used in categorising the QoC in the confidential enquiry into maternal deaths and severe morbidity in the UK (Knight et al.2014b).

#### **2.4.4. Strengths and limitations of the review**

The review has some limitations that should be acknowledged. A major limitation was the exclusion of non-English language papers. These excluded papers might present a different picture. Generally, English is considered the language of science, therefore few citations might be excluded. Likewise, by restricting the search to published papers in five databases, we might have missed work published elsewhere, and unpublished work. However, the included databases are the leadings databases in health and medical science, and they capture the majority of published work in the field. Studies in high-income countries were under-represented, which could be due to the exclusion of papers reporting a single condition. Despite these limitations, this systematic review is the first attempt to examine the methods and use of quality indicators related to MNM, capturing published work spanning around a decade.

### **2.5. Chapter summary and implications for the study methodology**

The findings of a systematic review to identify and explore how MNM has been used to assess the QoC, particularly examining the methods of implementations and indicators were presented in this chapter. 98 articles were included, about three-quarters of which were from LMIC. The majority were facility-based, mainly from tertiary healthcare facilities. The methods identified include survey, surveillance, citation-based review, facility review, and confidential enquiry. Each method has strengths and limitations, thus using combination is the best strategy for assessing the QoC. In-depth review of MNM is the most the useful method to explore the different dimensions of QoC.

QoC were assessed using the proposed WHO indicators, and “other indicators”. The proposed WHO indicators focused mainly in measuring the frequency of occurrence of MNM and use of key interventions as a proxy for QoC in terms of proportion and ratio. However, the indicators are limited to measure the reasons for substandard care. Also, a number of studies had contradictory results for the two categories of

process and outcome indicators. Therefore, these indicators need to be supplemented with other indicators to have a better understanding of QoC.

Although MNM criteria *per se* were not the focus of the review, it was noted that there is a persistent variation in the criteria used for the identification of MNM. The WHO criteria have been criticised for underestimating MNM and being difficult to apply in some contexts.

These findings informed the methodology of this research, which is presented in the next chapter. Briefly, survey with in-depth review of cases using facility review and confidential enquiry were selected and combined for this study. New identification criteria were developed using the disease-specific approach. The following indicators were selected to measure incidence of MNM:

- Ratio of MNM per 1,000 live births,
- SMO per 1,000 live births
- MNM: 1MD ratio
- MI for international comparison.

The proportion of cases that received good care and proportion of those with room for improvement in QoC are determined based on the findings of in-depth review.

### 3. Methodology

This research was conducted in the Sultanate of Oman in collaboration with the MoH-Oman, supported by WHO and UNFPA. The research integrated the MNM review into the well-established national maternal death review system in Oman to provide more information on where and how to improve the QoC to reduce both maternal mortality and morbidity.

This chapter presents the methodology of the study using the Strengthening the Reporting of Observational Studies in Epidemiology Guidelines (STORBE) for reporting observational studies (Elm et al., 2008). It presents the research questions followed by describing the study design, including the rationale for the selection of the research approach. It then describes the study setting, with reasons for the selection of healthcare facilities to identify women with MNM. This is followed by defining the target population, a presentation of the inclusion and exclusion criteria of the participants and a description of the development of the identification criteria for MNM used in the study.

Study variables are presented with description of data sources, the collection processes, and measures taken to ensure quality and integrity of data. Finally, the chapter ends by presenting the analysis plan and discussing ethical considerations and the positionality of the researcher throughout the study.

#### 3.1. Research questions

The following are the questions presented in chapter 1 with specification of MNM indicators that will be measured as discussed in chapter 2:

- What is the incidence of MNM in Oman? What are the values of MNM ratio, SMO ratio, MI and MNM: 1MD for Oman?
- What are the causes of MNM?
- What are the contributory conditions to MNM?
- What is the standard of care the women with MNM received?

- What are the factors associated with MNM events?

### **3.2. Study design**

This is a national prospective longitudinal (cohort) study. A prospective design is more appropriate to measure an incidence of disease than retrospective design. The latter can underestimate the true incidence due to misclassification of cases in the medical record, availability of these records, coding errors in diagnosis, and the correctness of the diagnosis of conditions under investigation (Almerie et al., 2010; Ali et al., 2011).

Based on the literature review presented in the previous chapter and consultation with key stakeholders in Oman and globally, the study used a combination of survey, with in-depth review at facility level, and confidential enquiry into maternal morbidity to go beyond counting the numbers to in-depth review of cases. Survey was utilised to measure the incidence of MNM and MNM indicators, while in-depth review was selected to assist in identifying the main causes of, contributory conditions to, and factors associated with MNM (**Figure 3.1**). In-depth review also assists in identifying substandard care and highlights key areas that need to be addressed (Lewis, 2003).

### **3.3. Study setting**

#### **3.3.1. Overview and rationale**

The study was conducted in Oman. Background about Oman and its healthcare system was described in chapter 1. Briefly, it is a high-income country that is divided into eleven governorates. MoH is the main healthcare provider in the country, and it has tertiary healthcare facilities, secondary care in the form of regional hospitals, and PHC. The latter includes health centres, and local and district hospitals.

The women with MNM were identified at the healthcare facility level, because almost all pregnant women (99%) in Oman are registered within a healthcare facility for ANC, which ensures that status and outcome are documented throughout pregnancy from registration until the postnatal period (up to six weeks postnatal). Also, 99% of deliveries take place in the health facilities (DoH I&S, 2017).

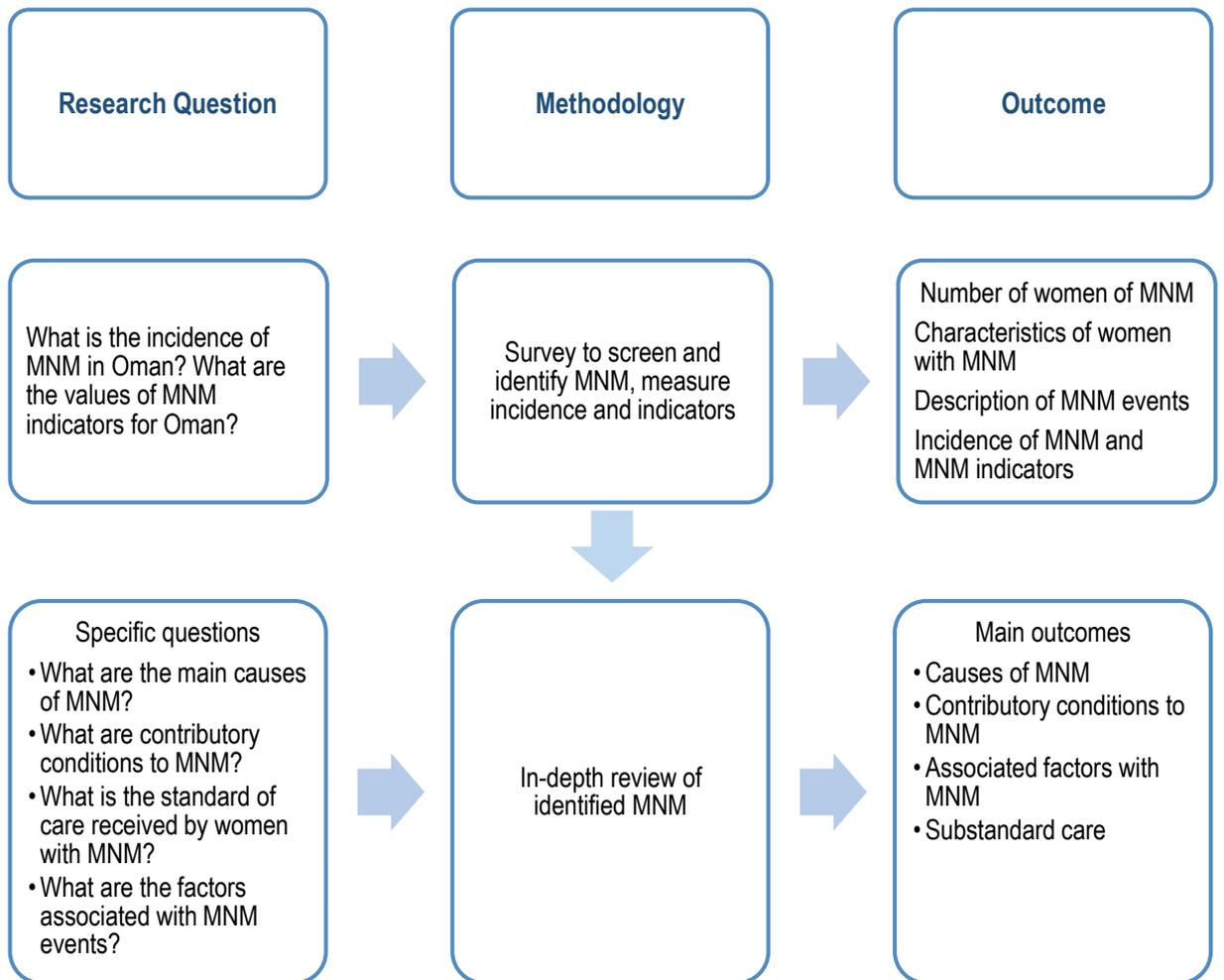


Figure 3.1: Research questions and methodological approach

The participating healthcare facilities were selected from across the country because of the variation in the distribution of the population, healthcare facilities, and total number of deliveries between governorates (**Table 3.1**). For instance, the highest number of regional hospitals which are referral hospitals for severe cases is in Muscat (the capital city). These hospitals in Muscat also act as national referral hospitals for critical cases from other governorate hospitals. In Oman the total number of deliveries is relatively small, and varies between governorates and individual health facilities.

*Table 3.1: Population, distribution of health services and births per governorate*

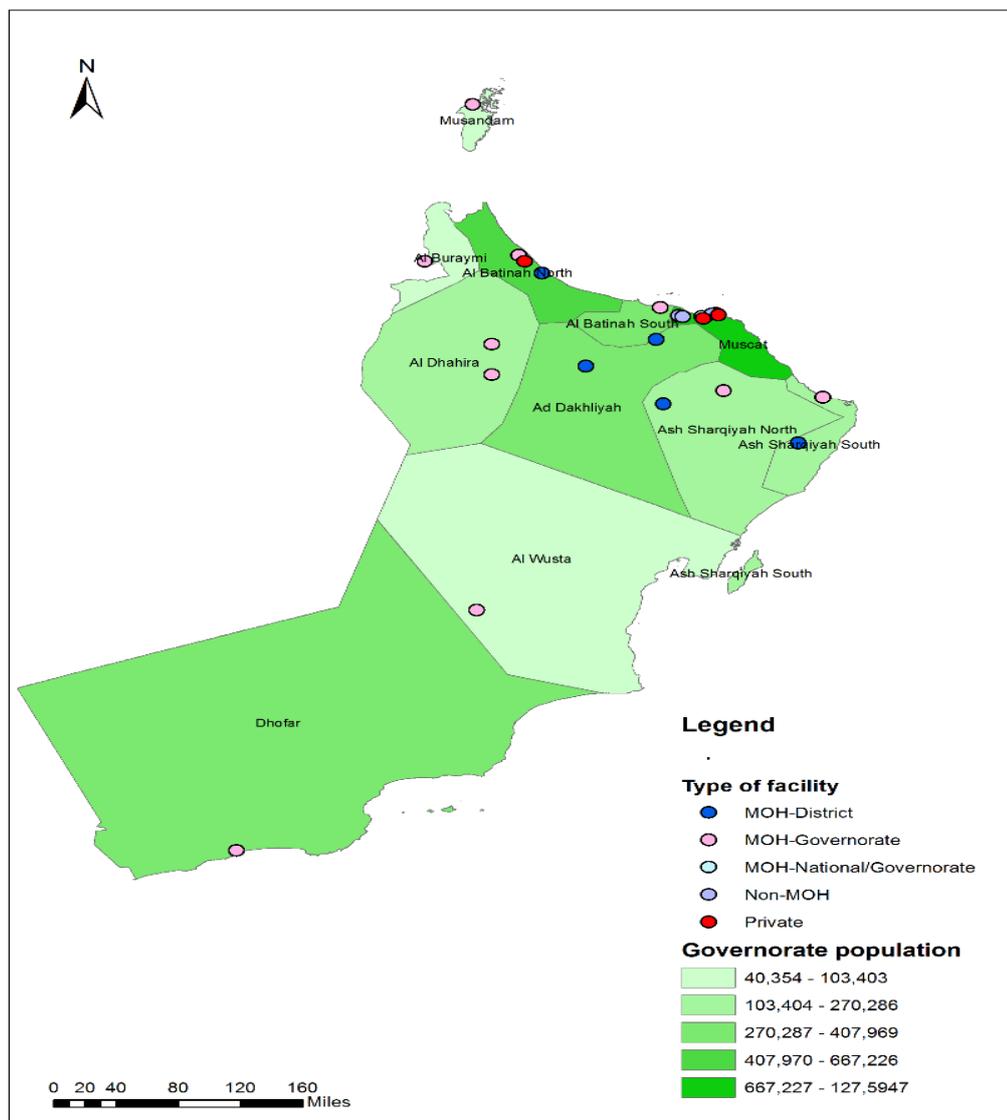
Governorate	Total population in the governorate and % of total population in Oman	No. hospitals (per category)			No. health centres	Total no. deliveries in 2017 (in MoH facilities)
		Regional	District	Local		
Muscat	1,459,249 (32.0)	4	0	2	32	15,760
Al Batinah North	754,169 (17.0)	1	1	3	25	10,045
Al Batinah South	417,847 (9.0)	1	0	4	22	7,553
Dhofar	457,622 (10.0)	1	0	6	42	7,220
Musandam	44,571 (1.0)	1	0	2	4	485
Ad Dakhliyah	461,199 (10.0)	1	2	3	25	10,060
Adh Dhahirah	213,771 (5.0)	1	0	1	18	4,643
Ash Sharqiyah South	312,822 (7.0)	1	1	2	24	7,019
As Sharqiyah North	279,223 (6.0)	1	1	4	22	6,217
Al Buraymi	114,334 (3.0)	1	0	1	3	1,854
Al Wusta	45,156 (1.0)	1	0	2	10	106
<b>Total</b>	<b>4,559,963</b>	<b>14</b>	<b>5</b>	<b>30</b>	<b>256</b>	<b>70,926</b>

Source: DoH I&S (2017)

Based on the data shown in **Table 3.1**, it was assumed that conducting national study and selecting healthcare facilities from across the country would assist in recruiting a representative and sufficient sample from the whole population, thereby enabling estimation of MNM incidence with adequate precision, and increasing the accuracy of the generalisation of the findings to the entire country.

The study included a total of 23 healthcare facilities conducting 90.7% (77,675) of the annual deliveries in Oman in the year preceding the study (2015). These facilities were distributed across the county, as shown in **(Figure 3.2)**, representing both governmental and private facilities. These facilities were selected using purposive sampling method considering:

- The total number of deliveries in the healthcare facility
- Number and place of maternal deaths
- Type of services in the healthcare facility
- Government (public) and private sectors



*Figure 3.2: Distribution of the participating hospitals*

### *3.3.1.1. Selection of governmental healthcare facilities*

16 out of 23 sites were MoH facilities, because most of the deliveries take place in MoH healthcare facilities. In 2015 (the preparation year for the study), the MoH had 81.2% of net facilities' deliveries (**Figure 3.3**). Within the MoH facilities, 95.1% of all deliveries took place in governorate and district hospitals, and all high-risk pregnancies were referred to these facilities. Moreover, district hospitals act both as primary and secondary health facilities in some places. Thus, all the 12 governorate hospitals (in Muscat two hospitals are considered as governorate hospitals) were included as study sites, as well as all district hospitals (n = 5). Local hospital and health centres manage low-risk pregnancies, and very few women give birth at this level (4.9%), thus they were not included.

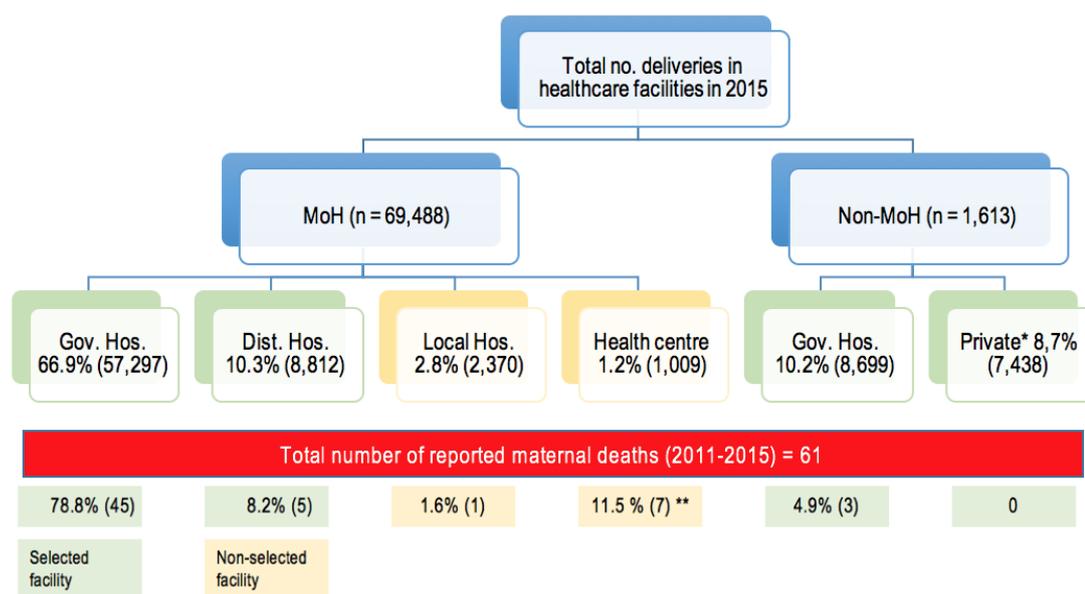
There are three non-MoH governmental healthcare facilities (hospitals) with in-patient services, which have a total of 97 beds for obstetrics and gynaecology services, providing 10.2% (n = 8,699) of total deliveries in 2015 (DoH I&S, 2016). Among these, the highest number of beds and deliveries are in the Sultan Qaboos University Hospital, which is a teaching tertiary care hospital. The Armed Forces Hospital provides secondary care and some tertiary services, while the Royal Oman Police Hospital mainly provides primary and some secondary care services. These three facilities were also recruited in the study to ensure teaching and other delivery level hospitals included.

### *3.3.1.2. Selection of private healthcare facilities*

The private sector provides only 7.5% of total hospital beds in the country, and it has a negligible role in maternity care (DoH I&S, 2016). There are only 14 private facilities with delivery services, which collectively conducted 8.7% (7,438) of all deliveries recorded in Oman in 2015 (**Figure 3.3**). In general, the private sector does not usually deal with severe complications, because they do not have the resources to manage such cases, thus they routinely refer such cases to governmental hospitals. However, to ensure a representative sample of the private sector, three facilities with 38.5% of the total deliveries in 2015 were selected based on the total number of deliveries at each healthcare facility, location, and type of services.

Most of the private facilities are in Muscat (10 healthcare facilities with 4,376 deliveries in 2015), followed by North Batinah (2 facilities with 2621 deliveries) then Dhofar (2 facilities with 495 deliveries) (DoH I&S, 2016). Thus, two hospitals were included from Muscat (from different locations) with high numbers of deliveries and

catering for different kinds of patients. One facility was recruited from North Batinah with a substantial number of deliveries. The facilities in Dhofar were not recruited because they do not have the capacity to manage severe complications and would therefore be unlikely to handle cases of MNM.



\* 3 private facilities were included in the study

\*\* All deaths reported from health centres after collapse at home

Figure 3.3: Distribution of deliveries and maternal deaths in Oman

### 3.3.1.3. Maternal deaths and selection of healthcare facilities

There were 61 maternal deaths reported between 2011 and 2015. 86.9% (n = 53) of all maternal deaths (n = 61) occurred at the selected facilities (**Figure 3.2**). About 73.8% (n = 45) of these deaths occurred in regional hospitals, followed by district hospitals (n = 5) and non-MoH governmental hospitals (n = 3). There were seven deaths notified from health centres, but these were related to maternal collapse at home, and the deaths did not occur within the centres.

It is unlikely that maternal deaths are missed from maternal deaths surveillance, because the maternal deaths data are cross-checked with National Death and Births Statistics.

### 3.3.1.4. Characteristics and services provided in the included facilities

The selected healthcare facilities represented primary, secondary, and tertiary facilities. The majority are equipped to manage complicated pregnancies and deliveries. It was expected that women with severe complications would be referred to and/ or receive care in these facilities. There were three tertiary care facilities with

sub-specialities services. Nine of the facilities provided secondary care with consultant-led teams and had an ICU, blood bank, and laboratory services. The remaining provided a mix of primary and secondary services, except two which provide primary care services only. All the participating healthcare facilities are hospitals. **Table 3.2** presents the characteristics of these hospitals using the code allocated for each during the study.

Table 3.2: Total deliveries and category of the included hospitals (2015)

Governorate	Hospital code	Total no. deliveries, 2015	PHC	Secondary hospital	Tertiary	Private
Muscat	1	8,691			X	
	2	5,831			X	
	3	4922			X	
	4	3235		X		
	5	542	X	X		
	21	1573				X
	23	584				X
Al Batinah North	7	1,381	X			
	8	9,235		X		
	22	1, 73				X
Al Batinah South	6	6,857		X		
Dhofar	20	6,777		X		
Musandam	9	324		X		
Ad Dakhliyah	12	6,440		X		
	13	1440	X	X		
	14	872	X			
Adh Dhahirah	10	4,282		X		
Ash Sharqiyah South	17	3,434		X		
	18	2,853	X			
As Sharqiyah North	15	3,478		X		
	16	2,266	X			
Al Buraymi	9	1,900		X		
Al Wusta	19	48	X			
<b>Total:</b>		<b>77,675</b>				

### 3.4. Target population, inclusion and exclusion criteria

Figure 3.4 illustrates the target population, inclusion and exclusion criteria, defined below:

**Target population:** All women admitted during pregnancy, intrapartum, or within 42 days of delivery or termination of pregnancy to a participating hospital during the study period.

**Inclusion criteria:** All women admitted or referred to a participating hospital who meet the criteria for PTLC and MNM during pregnancy, delivery irrespective of gestational age, or delivery status up to 42 days of termination of pregnancy.

**Exclusion criteria:** women were excluded if they were admitted before the commencement of the study (1st October 2016) or developed complications after 42 days from termination of pregnancy.

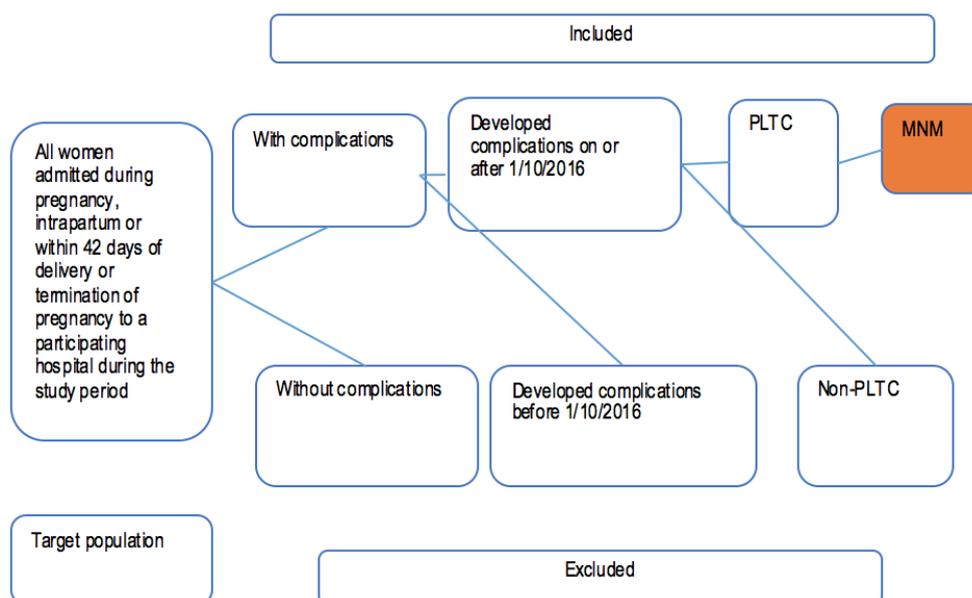


Figure 3.4: Target population, inclusion and exclusion criteria for the study

### 3.5. Expected number of MNM

Based on the WHO MNM approach (WHO, 2011), the prevalence of SMO was estimated to be 7.5 per 1,000 deliveries (**Table 3.3**). Using the same estimation, for the total deliveries in the participating hospitals using the figures in 2015 ( $n = 77,675$ ), the expected number of women with PLTC was around 2,874, and 583 women with SMO (DoH I&S, 2015). SMO is the total number of maternal deaths and MNM (WHO, 2011). Given the average of maternal deaths from 2011 to 2015 in Oman ( $n = 12$  per year), the expected number of MNM was around 571. However, it should be noted that these figures reflect the prevalence (new and old cases) of PLTC, SMO and MNM. Therefore, as the study aiming to estimate the incidence of MNM, the expected number of MNM will be less than 571.

Table 3.3: WHO estimation of prevalence of SMO and the expected number of MNM in Oman

Expected no. all eligible women and women with SMO based on WHO MNM approach assumptions					Oman (participating hospitals)
No. deliveries	1,000	2,000	4,000	10,000	77,675
Expected no. women with PLTC (range)	37 (15-75)	75 (37-300)	150 (75-300)	375 (187-750)	2,874
Expected no. women SMO (range)	7.5 (3-15)	15 (7-30)	30 (15-60)	75 (37-150)	583
Expected no. MNM for Oman	NA	NA	NA	NA	571

### **3.6. Identification of an MNM**

Based on the findings of the systematic review and discussion presented in chapter 2 regarding the challenges using with the WHO criteria, it was decided to develop new criteria to be used to identify MNM cases in this study. The new criteria follow the principle or the approach of disease-specific criteria by starting with disease or conditions, then identifying its complications, followed by defining the severe morbidity form of these complications and their severity markers. Starting from the wider group of severe complications rather than going directly to the markers (criteria) of MNM is more practical and feasible to apply in a clinical setting. This approach is also useful for calculating the complication rate and assessing QoC for a particular disease.

#### **3.6.1. Development of MNM criteria for the study in Oman**

To optimise identification of MNM cases, identification criteria for this study were developed based on the ICD-MM. It can be assumed that conditions that can result in maternal death would initially have been presented as, or been preceded by, severe morbidity (WHO, 2012). This linking also facilitates comparison between the primary cause of and contributory conditions to both maternal death and MNM. Secondly, it addresses the need highlighted in previous research to include a broader list of potential causes of MNM, in particular indirect causes of deaths such as cardiac, diabetes, and mental disease issues. Generally, there is a tendency to overlook these causes, despite their significant contribution to maternal deaths and morbidity (Storm et al., 2014). The ICD-MM is the application of International Classification of Diseases and Related Health Problems (ICD-10) to deaths during pregnancy, labour and puerperium. It categorises the underlying cause of maternal deaths into eight groups. In addition, a ninth group (coincidental) is allocated for accidental or incidental causes (WHO, 2012). The development of these criteria consisted of the following steps:

- Identifying common severe complications, PLTC and corresponding MNM markers(criteria) for each ICD-MM group
- Consulting international and national experts on these criteria
- Sharing the identification approach and list of PTLC and MNM criteria with national stakeholders
- Testing the identification approach, PTLC list and the MNM criteria (Pilot study is described in section 3.11 Quality assurance and control).

**Figure 3.5** illustrates the steps involved in selecting the PLTC and MNM criteria for each ICD-MM group.



*Figure 3.5: Process of development of PLTC list and MNM criteria for this study*

#### *3.6.1.1. Identify conditions that could cause severe morbidity*

Each ICD-MM group was examined to identify and list conditions from each group that are more likely to cause severe morbidity. The first seven groups of ICD-MM were selected only in the development of the criteria, as the eighth represents unknown causes of death. It was expected that if a woman survived severe complications, the underlying cause would be known. However, a category of other complications was added to capture those severe complications that can result in MNM but which did not belong to the first seven groups, including trauma and cancer cases.

#### *3.6.1.2. Identify possible PLTC for each condition*

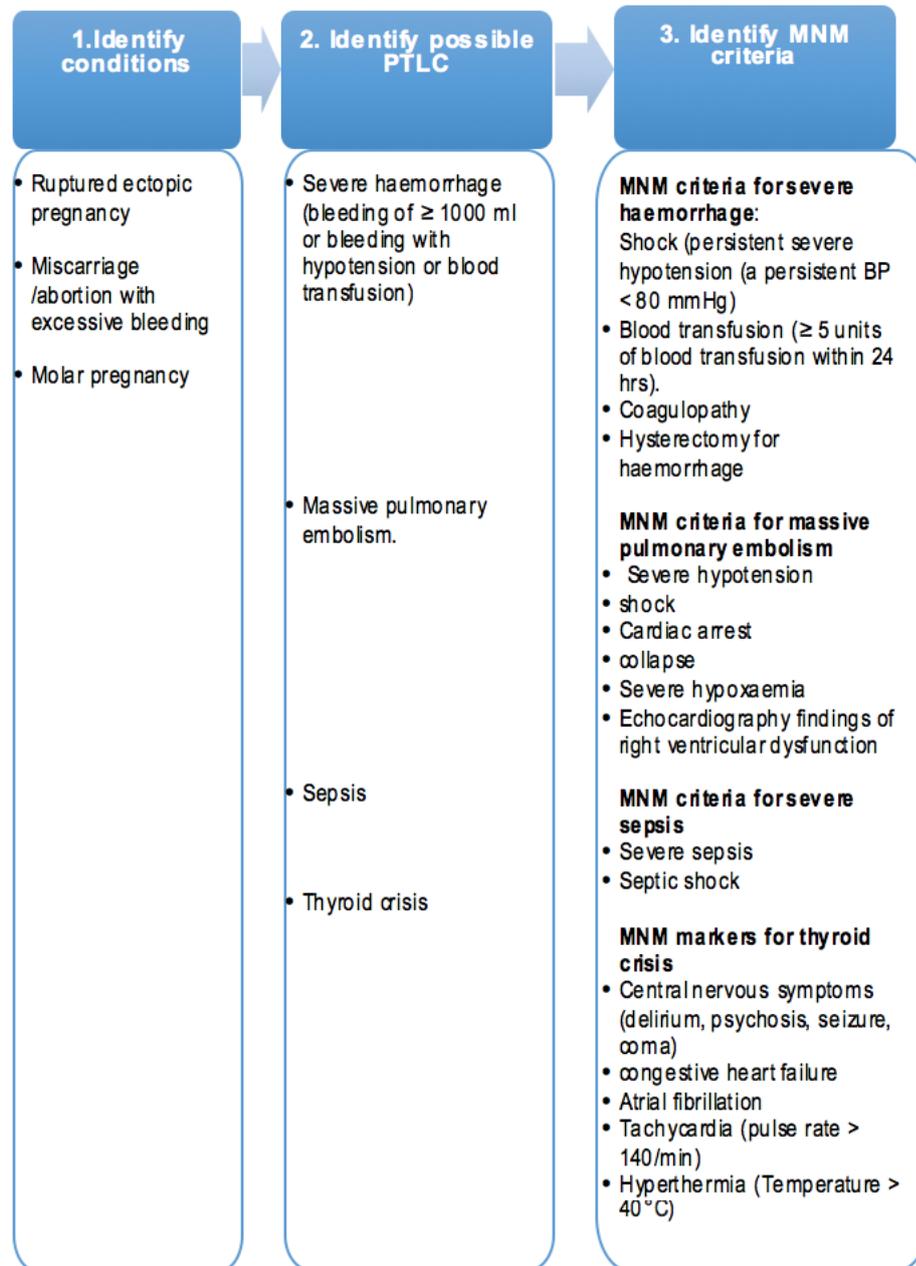
The severe complication(s) that could arise from these conditions and can be PLTC were identified using the WHO definition of PLTC: “clinical conditions, including diseases that can threaten a woman’s life during pregnancy and labour and after termination of pregnancy” (WHO, 2011). The selection of list of PLTC were all based on an extensive literature search to identify all possible and commonly reported severe conditions that can be potentially life-threatening for each group. The search included searching databases such as Medline, and websites of internationally known MNM surveillance and review systems (e.g. UKOSS).

#### *3.6.1.3. Identify MNM criteria (severity markers)*

The corresponding markers for each PLTC that could indicate the severity of the condition and ultimately a diagnosis of MNM were identified. The number and type of markers differ from one condition to another, and could consist of clinical, laboratory and management markers. The MNM severity markers and values were adopted from internationally accepted scoring systems, such as Watoscfsky’s scoring system of thyroid storm, Swansea criteria for acute fatty liver, and previously

published MNM criteria, including WHO criteria. Some markers were adopted from previous MNM research, in particular UKOSS studies. This necessitated examining previously published MNM criteria.

**Figure 3.6** illustrates the above steps using an example of ICD-MM group 1: pregnancy with abortive outcome



*Figure 3.6: Demonstration of steps of development of MNM criteria using ICD-MM Group 1: Pregnancy with abortive outcome*

#### *3.6.1.4. Consulting international and national experts*

To ensure the validity of the identification approach, and list of PTLC and MNM criteria, a number of global and national experts in the field of maternal mortality, morbidity, and other related specialities were consulted. In addition to the PhD supervisors, a draft of the study proposal with the identification approach of MNM, including the list of PTLC and MNM criteria, was circulated for review by global experts in the maternal mortality and morbidity reviews, including the following:

- Professor of Maternal and Child Population Health at the University of Oxford and Director of Confidential Enquiry into Maternal Deaths, UK
- Lead for International Women's Health Research at the Institute for Women's Health, University College London, and previous Director of Confidential Enquiry into Maternal Deaths, UK
- Two members of the Epidemiology, Monitoring, and Evaluation Team in WHO's Department of Maternal, Newborn, Child and Adolescent Health in Geneva.

Meetings were held with these experts to discuss the approach and criteria. Overall, all experts found the approach to be suitable. Their main recommendations were related to the following:

- Use of blood transfusion of 5 units or more, if feasible for Oman.
- Adding group of "other complications" to capture MNM not related to the first seven groups of ICD-MM (in the initial draft, this group was not included).
- A suggestion to focus on selected groups of ICD-MM, such as obstetric haemorrhage and hypotensive disorders, rather than addressing all seven groups. The selection of the groups or conditions can be based on data of maternal deaths.

Related comments were circulated to senior national experts from Oman with international experience to review and comment, with the main focus of cross-checking the selected conditions and whether the procedures and values used in defining the criteria are applicable to Oman. These experts included the following:

- Four members from the National Maternal Mortality Committee
- Senior obstetricians
- Consultant clinical biochemistry
- Haematologists

- Physicians
- Anaesthetists

The experts found the whole approach useful and applicable in Oman. Their main comments were:

- Preferred to address the all seven groups of ICD-MM, as there was no previous study on severe maternal morbidity in Oman
- Confirm the values used in the criteria are applicable to Oman
- The cut off value of 5 units of blood transfusion is applicable to Oman
- Sharing the identification approach and list of PTLC and MNM criteria with national stakeholders

To ensure more local applicability, the approach was shared with wider stakeholders from across Oman. During a national consultation, the approach and criteria were presented and shared with staff from the MoH Headquarters, the heads of the obstetrics and gynaecology departments from different facilities, and members of both the National and Regional Maternal Mortality Committees. Following that, the materials were circulated to a wider group of senior obstetricians from across Oman.

#### *3.6.1.5. Testing the PTLC list and the MNM criteria*

As a final step, the identification approach and list of PTLC and MNM criteria were tested as part of a pilot study conducted for one month in eight facilities from three different governorates. The main outcomes of this approach were:

- The identification approach and markers were found practical and feasible to apply in a clinical setting, and values of the markers were suitable for Oman.
- It was recommended to expand the list of PTLC of some groups to capture more severe complications, in particular the group of non-obstetric complications, to include for example the complications related to the gastrointestinal tract (GIT).
- Expand the MNM criteria related to severe haemorrhage to include coagulopathy, and the one related to sepsis to include admission to ICU.

The final list of PTLC and MNM is presented in **(Table 3.4)** for each ICD-MM group.

Table 3.4: ICD-MM group, maternal condition, potentially life-threatening condition and criteria derived to define MNM

Maternal condition	Potentially life-threatening condition	Criteria for identification of case of MNM
Group 1: Pregnancy with abortive outcome		
Ruptured ectopic pregnancy Miscarriage/ abortion with excessive bleeding Molar pregnancy	Severe haemorrhage (bleeding of $\geq 1000$ ml or bleeding with hypotension or blood transfusion) (WHO, 2011)	Shock (a persistent systolic blood pressure $< 80$ mmHg or a persistent systolic blood pressure $< 90$ mmHg with a pulse rate at least 120 beats per minute) (WHO, 2011) Coagulopathy (acute thrombocytopenia ( $< 50,000$ platelets), low fibrinogen ( $< 100$ mg/dl), prolonged prothrombin time ( $> 6$ s, INR $> 5$ ), or elevated D-dimer ( $> 1000$ ng/dl) (WHO, 2011) Blood transfusion (five or more units of blood transfusion within 24 hours). Hysterectomy for haemorrhage
	Massive pulmonary embolism (severe acute onset of dyspnoea, chest pain, pre-syncope or syncope, and/or haemoptysis) (Konstantinides et al., 2014)	Severe hypotension (systolic blood pressure $< 80$ mmHg) Shock (a persistent systolic blood pressure $< 80$ mmHg or a persistent systolic blood pressure $< 90$ mmHg with a pulse rate at least 120 beats per minute) Cardiac arrest (sudden absence of pulse and loss of consciousness) Collapse (loss of consciousness) Severe hypoxaemia (oxygen saturation $< 90\%$ for $\geq 60$ minutes or $\text{PaO}_2/\text{FiO}_2 < 200$ ) Echocardiography findings of right ventricular (RV) dysfunction: RV dilation and/or an increased end-diastolic RV–LV diameter ratio Myocardial injury (e.g. elevated cardiac troponin I or -T concentrations in plasma), or of heart failure as a result of (right) ventricular dysfunction Computed tomographic pulmonary angiography findings of massive pulmonary embolism
	Sepsis: Presence of infection with two of the following: (temperature $> 38^\circ\text{C}$ or less than $36^\circ\text{C}$ , heart rate $> 100$ beats/min measured in two occasions 4hrs apart, respiratory rate $> 20$ breaths/min measured in two occasions 4 hrs apart, WBC $> 17 \times 10^9/\text{l}$ or $< 4 \times 10^9/\text{l}$ ) (Acosta et al., 2012)	Severe sepsis (sepsis associated with organ dysfunction, hypoperfusion, or hypotension, which may include but not be limited to lactic acidosis, oliguria, or an acute alteration in mental status) Septic shock: persistence of hypoperfusion despite adequate fluid replacement therapy Admission to high dependency unit (HDU) or intensive care unit (ICU) (Acosta et al., 2012)
	Thyroid crisis (Singh et al., 2016): Acute endocrine emergency resulting from overproduction of thyroid hormones. Can be diagnosed using Wartofsky criteria, including the following (depending on severity); hyperthermia, cardiovascular dysfunction (tachycardia, atrial fibrillation, congestive heart failure), central nervous symptoms (agitation, delirium,	Central nervous symptoms (delirium, psychosis, seizure, coma) Congestive heart failure Atrial fibrillation Tachycardia (pulse rate $> 140/\text{min}$ ) Severe gastrointestinal/ hepatic dysfunction (unexplained jaundice) Hyperthermia (temperature $> 40^\circ\text{C}$ )

Maternal condition	Potentially life-threatening condition	Criteria for identification of case of MNM
	psychosis, extreme lethargy, seizure, coma) and gastrointestinal/hepatic dysfunction (diarrhoea, nausea, vomiting, unexplained jaundice)	
<b>Group 2: Hypertensive disorders of pregnancy</b>		
Pre-existing hypertension with superimposed proteinuria Pregnancy induced hypertension with or without proteinuria	Severe pre-eclampsia (NICE, 2010) BP is $\geq 160$ mmHg systolic and/or $\geq 110$ mmHg diastolic with symptoms: a severe headache, problems with vision, such as blurring or flashing before the eyes, severe pain just below the ribs, vomiting, sudden swelling of the face, hands or feet Biochemical and/or haematological impairment Eclampsia: generalised fits in a patient without previous history of epilepsy)	Pulmonary oedema (Dennis and Solnordal, 2012) (breathlessness, orthopnoea, agitation, cough, tachycardia, tachypnoea, crackles and wheeze on chest auscultation, cardiac S3 gallop rhythm and murmurs, decreased oxygen saturation) Jaundice Eclampsia (WHO, 2011) (generalised fits in a patient without previous history of epilepsy) Thrombocytopenia (platelets count $< 100,000, 109 /l$ ) Impaired renal function (serum creatinine $\geq 1.1$ mg/l or a doubling of the serum creatinine concentration in the absence of another renal disease) Impaired liver function (elevated liver transaminases to twice normal concentration)
	HELLP syndrome (Fitzpatrick et al., 2014) (haemolysis, elevated liver enzyme, low platelet)	Haemolysis (abnormal (fragmented or contracted red cells) peripheral blood smear or serum lactate dehydrogenase levels 600 international units/l or greater or total bilirubin 20.5 micromole/l or greater) Elevated liver enzymes (serum aspartate aminotransferase 70 international units/l or greater OR Gamma-glutamyl transferase 70 international units/l or greater alanine aminotransferase 70 international units/l or greater) Low platelet (platelet count less than $100,000 \times 10^9/l$ )
<b>Group 3: Obstetric haemorrhage</b>		
Antepartum haemorrhage (placental abruption, placenta previa/ accrete/ increta/ percreta) Intrapartum haemorrhage Rupture of uterus Postpartum haemorrhage (uterine atony, pelvic haematoma/ laceration of cervix/ vaginal laceration)	Severe haemorrhage (WHO, 2011) (Bleeding of $\geq 1000$ ml or bleeding with hypotension or blood transfusion)	Shock (persistent severe hypotension (a persistent BP $< 80$ mmHg or persistent systolic BP $< 90$ mmHg for $\geq 60$ minutes with a pulse rate at least 120 despite fluid replacement ( $> 2L$ )) Coagulopathy (acute thrombocytopenia ( $< 50,000$ platelets), low fibrinogen ( $< 100$ mg/dl), prolonged prothrombin time ( $> 6$ s, INR $> 5$ ), or elevated D-dimer ( $> 1000$ ng/dl))  Blood transfusion (5 or more units of blood transfusion within 24 hours) Hysterectomy for haemorrhage
<b>Group 4: Pregnancy-related infection</b>		
Infections of genitourinary tract Chorioamnionitis Puerperal sepsis	Sepsis Presence of infection with two of the following: (temperature $> 38^\circ C$ or less than $36^\circ C$ , heart rate $> 100$ beats/min measured in two occasions 4 hrs apart, respiratory rate $> 20$ beats/min measured in two occasions 4	Severe sepsis (Acosta et al., 2012) (sepsis associated with organ dysfunction, hypoperfusion, or hypotension which may include but not be limited to lactic acidosis, oliguria, or an acute alteration in mental status) Septic shock: persistence of hypoperfusion despite adequate fluid replacement therapy Admission to HDU or ICU

Maternal condition	Potentially life-threatening condition	Criteria for identification of case of MNM
	hrs apart, WBC > 17 x 10 <sup>9</sup> /l or < 4 x 10 <sup>9</sup> /l)	
Group 5: Other obstetric complications		
Obstetric embolism	Amniotic fluid embolism (AFE) (Knight et al., 2010): in the absence of any other cause acute maternal collapse during labour or delivery or within 30 minutes of delivery with at least one or more of the following: hypotension, sudden onset of breathing, cardiac rhythm problems, cardiac arrest, seizure, premonitory symptoms (e.g. restlessness, anxiety, agitation), maternal haemorrhage and acute foetal compromise	Acute hypotension (systolic BP < 80 mmHg) Coagulopathy (WHO, 2011) (acute thrombocytopenia (<50,000 platelets), low fibrinogen (<100 mg/dl), prolonged prothrombin time (>6s, INR>5), or elevated D-dimer (>1000 ng/dl)). Cardiac arrest (sudden absence of pulse and loss of consciousness) Seizure
	Massive pulmonary embolism: (severe acute onset of dyspnoea, chest pain, pre-syncope or syncope, and/or haemoptysis)	Severe hypotension (systolic blood pressure <80 mmHg) Shock (a persistent systolic blood pressure <80 mmHg or a persistent systolic blood pressure <90 mmHg with a pulse rate at least 120 beats per minute) Cardiac arrest (sudden absence of pulse and loss of consciousness) Collapse (loss of consciousness) Severe hypoxaemia (oxygen saturation <90% for ≥60 minutes or PaO <sub>2</sub> /FiO <sub>2</sub> <200) Echocardiography findings of right ventricular (RV) dysfunction: RV dilation and/or an increased end-diastolic RV–LV diameter ratio Myocardial injury (e.g. elevated cardiac troponin I or -T concentrations in plasma), or of heart failure as a result of (right) ventricular dysfunction) Computed tomographic pulmonary angiography findings of massive pulmonary embolism
Cardiac complications	Peripartum cardiomyopathy	Pulmonary oedema Shock Cardiac arrest Severe hypo-perfusion Cardiopulmonary resuscitation Use of continuous vasoactive drug Intubation and ventilation
Liver disease in pregnancy	Acute fatty liver (Criteria adopted from Ch'ng et al., 2002; values are adopted from Knight et al., 2008): 6 or more of the following in the absence of any other cause: Vomiting Abdominal pain Polydipsia/polyuria Encephalopathy Hyperbilirubinemia (> 14 µmol/l) Hypoglycaemia (<4mmol/l) Elevated uric acid (>340 µmol/l) Leucocytosis	Hepatic encephalopathy (Weissenborn, 2014) (presence of neuropsychiatric symptoms and signs such as abnormal movements like shaking hands, agitation, disorientation, drowsiness or confusion, etc.) Convulsion Renal impairment (increase in creatinine and urea (creatinine ≥300 µmol/l or 3.5 mg/dl)) Coagulopathy (acute thrombocytopenia (<50,000 platelets), low fibrinogen (<100 mg/dl), prolonged prothrombin time (>6s, INR>5), or elevated D-dimer (>1000 ng/dl)). Admission to HDU or ICU Intubation or ventilation not related to anaesthesia Renal dialysis

Maternal condition	Potentially life-threatening condition	Criteria for identification of case of MNM
	Ascites or bright liver on the US elevated transaminases (aspartate aminotransferase or alanine aminotransferase > 42 IU/l) Elevated ammonia (> 47 mmol/l) Renal impairment creatinine >150 mmol/l Coagulopathy (prothrombin time >14 s or activated partial thromboplastin time > 34 s)	
Obstetric trauma	Postpartum inversion to uterus (Bhalla et al., 2009): “the turning inside out of the fundus into the uterine cavity obstetric trauma/injury to the bladder and other abdominal or pelvic organs”	Acute hypotension Neurogenic shock (pale, and sweating, with profound hypotension with bradycardia) Hypovolemic shock (persistent systolic blood pressure <80 mmHg or a persistent systolic blood pressure <90 mmHg with a pulse rate at least 120 beats per minute) Blood transfusion (5 or more units)
Intentional self-harm	Suicidal attempt (NICE Clinical Guideline 16, 2004) “self-poisoning or self-injury, irrespective of the apparent purpose of the act”	Total paralysis Coma Cardiac arrest (sudden absence of pulse and loss of consciousness) Azotaemia (creatinine $\geq 300 \mu\text{mol/l}$ or 3.5 mg/dl) Coagulopathy (acute thrombocytopenia (<50,000 platelets), low fibrinogen (<100 mg/dl), prolonged prothrombin time (>6s, INR>5), or elevated D-dimer (>1000 ng/dl)) Hepatic dysfunction; elevated liver enzyme (serum aspartate aminotransferase 70 international units/l or greater OR gamma-glutamyl transferase 70 international units/l or greater alanine aminotransferase 70 international units/l or greater) Dialysis for acute renal failure Intubation and ventilation not related to anaesthesia Cardiorespiratory resuscitation
<b>Group 6: Unanticipated complications of management</b>		
Anaesthesia	Cerebral anoxia due anaesthesia Aspiration pneumonitis Cardiac failure/assert Subdural haematoma/abscess cerebral venous sinus thrombosis post-dural anaesthesia Others	Collapse after anaesthesia Severe headache Cardiac arrest Admitted to ICU or HDU due to anaesthetic complications
<b>Group 7: Non-obstetric complications</b>		
Infection: H1N1 infection HIV with complication/s during pregnancy Other non- pregnancy-related infection	Severe pneumonia Sepsis	Severe sepsis (sepsis associated with organ dysfunction, hypoperfusion, or hypotension which may include but not limited to lactic acidosis, oliguria, or an acute alteration in mental status) Septic shock: persistence of hypoperfusion despite adequate fluid replacement therapy Admission HDU or ICU
Cardiac: Acute ischemic	Acute myocardial infarction Infective endocarditis	Pulmonary oedema (breathlessness, orthopnoea, agitation, cough, tachycardia, tachypnoea, crackles

Maternal condition	Potentially life-threatening condition	Criteria for identification of case of MNM
heart disease Cardiomyopathy Rheumatic heart disease with complication/s Pre-existing hypertension	Pulmonary hypertension Dissection of an aortic aneurysm Acute heart failure Acute atrial fibrillation Severe valvular heart disease Cardiomyopathy Severe acute hypertension (systolic BP $\geq 160$ mmHg, diastolic BP $\geq 110$ mmHg)	and wheeze on chest auscultation, cardiac S3 gallop rhythm and murmurs, decreased oxygen saturation) Shock (persistent severe hypotension (systolic BP $< 90$ mmHg for $\geq 60$ ) minutes with a pulse rate at least 120 despite fluid replacement ( $> 2L$ )) Cardiac arrest (absence of pulse/heartbeat and loss of consciousness) Stroke Severe hypoperfusion (lactates $> 5$ mmol/l or $> 45$ mg/dl, severe acidosis) Cardiopulmonary resuscitation Use of continuing vasoactive drug Intubation and ventilation not related to anaesthesia
Respiratory conditions	Severe asthma Severe chronic bronchitis Pulmonary oedema Pneumothorax Acute respiratory distress syndrome	Respiratory dysfunction (WHO, 2011) Acute cyanosis Gaspings Respiratory rate $> 40$ or $< 6$ bpm Oxygen saturation $< 90\%$ for $\geq 60$ min PaO <sub>2</sub> $< 200$ mmHg Intubation and ventilation not related to anaesthesia
Genitourinary: Chronic renal disease Thrombotic thrombocytopenic purpura Haemolytic-uremic syndrome Obstructive uropathy	Acute renal failure	Oliguria non-responsive to fluids or diuretics Creatinine $\geq 300$ $\mu$ mol/l or 3.5 mg/dl Renal dialysis
Haematological	Sickle cell disease with crises	Acute chest syndrome (Parrish and Morrison, 2013) (pulmonary symptoms and signs tachinid, chest pain, hypoxia with a new pulmonary infiltrate on chest X-ray) Admission to HDU or ICU Severe haemolysis and severe anaemia (Hb $< 6.0$ g/dL) Evidence of multi-organs failure Severe infection or evidence of sepsis Pulmonary embolism
	Thrombotic thrombocytopenic purpura (Moake, 2009): Thrombotic microangiopathy; systemic platelet aggregation, organ ischaemia, profound thrombocytopenia and fragmentation of erythrocytes)	Severe renal impairment Neurological involvement Cardiac involvement Admission to HDU or ICU
Endocrine	Thyroid crisis (Singh et al., 2016): An acute endocrine emergency that results from overproduction of thyroid hormones. It can be diagnosed using Wartofsky criteria which include the following (depends on the severity); hyperthermia, cardiovascular dysfunction (tachycardia, atrial fibrillation, congestive heart failure),	Central nervous symptoms (delirium, psychosis, seizure, coma) Congestive heart failure Atrial fibrillation Tachycardia (pulse rate $> 140$ /min) Severe gastrointestinal/ hepatic dysfunction (unexplained jaundice) Hyperthermia (temperature $> 40$ °C)

Maternal condition	Potentially life-threatening condition	Criteria for identification of case of MNM
	Central nervous symptoms (agitation, delirium, psychosis, extreme lethargy, seizure, coma) and gastrointestinal/hepatic dysfunction (diarrhoea, nausea, vomiting, unexplained jaundice)	
	Diabetes ketoacidosis (Joint British Diabetes Societies Inpatient Care Group, 2013) (ketonaemia (> 3.0mmol/l or significant ketonuria (more than 2+ on standard urine sticks)), hyperglycaemia (blood glucose > 11.0mmol/l, and acidaemia (bicarbonate < 15.0mmol/l and/or venous pH < 7.3 in diabetic patients))	Acute respiratory distress syndrome (respiratory failure with bilateral infiltration) Disorientation/ coma Severe acidaemia (PH < 7.1) bicarbonate < 10 mEq/l (10 mmol/l) Severe hypokalaemia
Central nervous system	Epilepsy Intracerebral and subarachnoid haemorrhage Convulsion of unknown origin	Uncountable fit/status epilepticus Total paralysis Stroke Prolonged unconsciousness (lasting ≥ 12 hours)/ coma)
Connective tissue	Flare of systematic lupus erythematosus Anti-phospholipid syndrome with complications	Presence of organ failure
GIT	Severe non-pregnancy-related liver diseases	Severe ascites Oesophageal variceal bleeding Hepatic encephalopathy (Weissenborn, 2014) (deterioration of brain functions due to liver disease) Coagulopathy
	Ruptured appendix Acute pancreatitis Acute cholecystitis Perforated gastro-duodenal ulcer Intestinal obstruction/perforation	Severe sepsis Shock Intubation and ventilation not related to anaesthesia Cardiopulmonary resuscitation
<b>Group 8: Other severe complications</b>		
Specify condition		Permanent neurological injury Prolonged unconsciousness or coma (lasting more than 12 hours) Shock Coagulopathy Organ failure (specify) Intubation and ventilation not related to anaesthesia Cardiopulmonary resuscitation Emergency hysterectomy

### 3.6.2. Data collection period

The cases of MNM were identified over one year (from 1st October 2016 to 30th September 2017) to recruit a sufficient sample and to address any seasonal variation that could affect the number of identified cases. For example, Etard, Kodio,

and Ronsmans (2003) and Houton et al. (2008) observed seasonality of maternal deaths and complications. In most populations, a variation in births rate was observed between different seasons of the year (Bobak and Gjonca, 2001). In 2015 (the year preceding data collection), the highest births rate in Oman was recorded in August (9.1%), September (8.8%) and October (8.9%) (DoH&S,2016). Also, during the same year, a slight variation was observed in the caesarean section rate per month with the highest rate was recorded in February (20.9%) and lowest in July (16.7%).

A collection of data over a long period increases a chance of capturing and understanding both common and uncommon underlying cause of MNM. On the other hand, a long period of data collection is expensive, increasing the risk of exhaustion of participating facility members in situations which could result in withdrawal from the study. To overcome this risk, different mechanisms were implemented, including providing support to hospitals in reporting the cases and sharing preliminary results.

### **3.6.3. Data collectors**

Focal persons identified MNM cases and collected relevant data. They were obstetricians working in the participating facilities. They were nominated by the heads of the obstetrics and gynaecology departments in each hospital, based on criteria developed by the PI, including working in the department of obstetrics and gynaecology, previous experience in research or audit, and willingness to participate in the research. To ensure the availability of a focal person throughout the study period, and considering the size of the hospitals and expected workload, each hospital was requested to nominate 2-3 personnel, with a support team formed within the department to assist these focal persons. For quality control, all focal persons were trained on the data collection process. Details of the training is presented under section 3.11 Quality assurance and quality control (3.11.1.3 Orientation and training on the study process and tools).

### **3.6.4. Process of identification and reporting of MNM**

Identification of MNM cases was carried out daily in all participating hospitals during the twelve months' data collection period. All women with severe complications were screened to identify those with potentially life-threatening conditions, from which MNM cases emerge, as described below and shown in **Figure 3.7**.

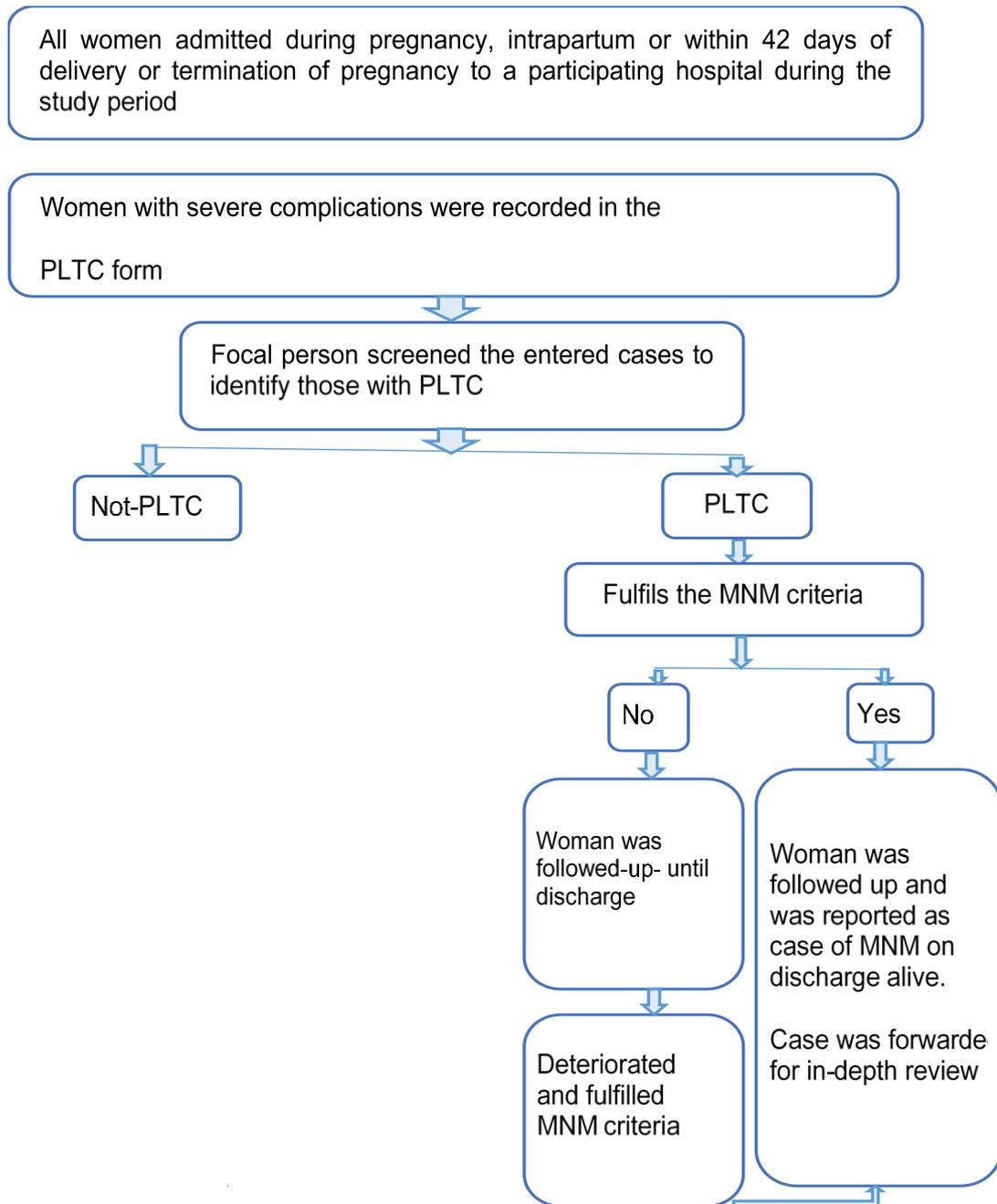


Figure 3.7: Screening and reporting cases of MNM

#### 3.6.4.1. Step 1: Screening cases with severe complication to identify women with PLTC

The focal persons actively searched for cases with PLTC and MNM by reviewing registers of the obstetric admission room, delivery suite, obstetric operation theatre, HDU, and all maternity wards, using the case definitions and criteria of PLTC as outlined in **Table 3.4** (ICD-MM group, maternal condition, potentially life-threatening conditions and derived criteria to define MNM). The same table was included in the study manual. Also, to identify these cases, the focal person attended the

department morning meetings, where usually the on-call team presented the admission of previous days.

In addition, all staff (doctors, midwives and nurses) in the departments of obstetrics and gynaecology were requested to record any case they attended with severe complications, with a view to considering whether the cases met the definition and criteria of PLTC in a special form designed for this purpose, called Form 1: Potentially Life-Threatening Condition (**Annex 3**). These staff were oriented on the PLTC list and MNM criteria.

To identify any cases admitted outside the obstetric department, staff in other departments (ICU, medical, and surgical wards) were oriented and requested also to record cases with severe complications in the PLTC form. The focal persons cross-checked the entry in the form and the admission in these departments to identify any admissions of pregnant women or those in the postpartum period who have not been not reported.

#### *3.6.4.2. Step 2: Screening women with PLTC to identify those with MNM*

The focal person screened all identified women with potentially life-threatening conditions to identify those fulfilling the MNM criteria using pre-designed form (Form 2: MNM identification form) (**Annex 4**). Once a woman with MNM case was identified, the focal person followed the progress of the woman until discharged. If woman survived the severe complication, the identification form was completed as MNM case and forwarded to PI within 7 days of discharge. The case note was forwarded for in-depth review.

Those women with PLTC but not satisfying the MNM criteria were followed up also in case their conditions deteriorated while in hospital. To facilitate the follow-up process, a unique study identification number was allocated for each identified woman.

In general, the outcome of both identified women with PLTC or MNM was recorded on discharge (dead, discharged in good condition, referred) in the PLTC form. Most medical records in Oman are computerised, which facilitated the process of follow-up and data extraction. To avoid duplication of notification of identified cases especially those who have been referred from one healthcare facility and another, it was decided that the last admitted and discharging hospital to notify all eligible cases. The name of referred healthcare facility should be recorded

It was not possible to follow-up the women after discharging if they developed another episode of PLTC or MNM due to the limitation of the available resources. However, data of the national maternal deaths was cross-checked if the recorded MNM cases died after they have been discharged.

### 3.7. MNM review

#### 3.7.1. Purpose of MNM review

The aim of the reviewing MNM was answer the research question related to the following.

- Underlying causes of MNM: the definition of underlying cause of MNM was adapted from the definition of underlying cause of maternal death, thus it was defined as “the disease or condition that initiated the morbid chain of events” that led to the MNM event (WHO, 2012, p.8). Similar to maternal death, it normally should be a single cause. The underlying cause of MNM was assigned using the ICD-MM groups followed by specifying the specific cause.
- Contributory conditions to MNM: conditions that may have contributed to or been associated with but which did not directly cause MNM (WHO, 2011, 2012). These conditions were divided into three categories: (1) maternal conditions, (2) conditions related to the foetus, and (3) interventions the women received that contributed to severe complication.

*Table 3.5: Contributory conditions to MNM*

Category of conditions	Examples
<b>Maternal conditions: maternal obstetric and medical conditions that could contribute to or aggravate severe complications</b>	Obstetric conditions: grand multiparous (had $\geq 5$ children), previous caesarean section, pelvic abnormality, prolonged obstetric labour, premature rupture of membrane, preterm labour/birth, prolonged pregnancy ( $\geq 42$ weeks of gestation). Medical conditions: anaemia, diabetes or other medical disorders, such as hypertension
<b>Foetal-related conditions</b>	Multiple gestation, foetal abnormality, abnormal presentation of foetus, polyhydramnios, oligohydramnios or other foetal condition that could had aggravated the maternal severe complication
<b>Interventions</b>	Failed induction of labour, failed trial of labour, failed vacuum extraction or forceps, or other interventions that had a serious effect of mother and aggravated her severe complication

### **3.7.2. Factors associated with MNM**

These are non-medical factors that contributed to the occurrence of severe morbidity event adapted from Farquher et al. (2011). They were also divided into three categories.

- Organisation of care and wider healthcare system: examined the elements related to the organisation of care and the wider healthcare system. It includes those related to function of health system from ensuring the availability and functioning of equipment, referral system (transportation problem and non-availability of bed in higher healthcare facility, staff (inadequate number of staff or poor access to senior staff), laboratory (non-availability of laboratory).
- Factors related to the attending healthcare team and examined the clinical aspect of the provided care by the healthcare team attended to the woman with MNM, such as delay in assessment or recognition of serious condition, delay in diagnosis and inappropriate management (prescription of medication, surgery, monitoring of the condition). It also investigates the delay in referral to higher care level, poor communication between different healthcare team and failure to involve other specialities.
- Factors related to the woman herself focus on issues related to the woman and her family that affected the outcome of woman health condition, like not attending ANC care, non-adherence to prescribed treatment, delay in seeking care, and long distance from healthcare facility.

### **3.7.3. Assessment of QoC the woman with MNM received (substandard care)**

The overall care the woman received was classified into three categories which were adopted from the classification used in the UK Confidential Enquiry into Severe Maternal Morbidity (Knight et al., 2018):

- Good care: cases without a deficiency in received QoC.
- Improvements in QoC were identified, but if these had been in place it would still have made no difference to the outcome: cases identified to have a deficiency in QoC, but improvement in care provided would have not changed the severe maternal outcome.
- Improvements in QoC were identified, if these had been in place it might have made a difference to the outcome: cases in which at least one

deficiency in QoC was identified, and if better care was provided, it could change or prevent the severe outcome.

#### **3.7.4. Process of MNM review**

The review of MNM was carried out sequentially at four levels (hospital, regional, national, and international) (**Figure 3.8**). Multiple reviews were needed to verify the reported underlying causes of, contributory conditions to, and factors associated with MNM as well as assessment of standard of care. It was assumed that findings of each level of review can complement findings of each other levels. Local reviewers have more understanding of local context and factors that affect the provision of care. However, they might be biased, especially if they were involved compared to external reviewers. Shah et al. (2016) reviewed a number of local reviews of severe maternal morbidity in the UK and compared lessons learned for future care between these local reviews and Confidential Enquiry into Maternal Morbidity and observed that the confidential enquiry identified more gaps, and lessons for improving future care compare to local reviews. Despite that, they acknowledged that local reviews identified local factors that cannot be identified by external reviewers that rely only on patient case notes.

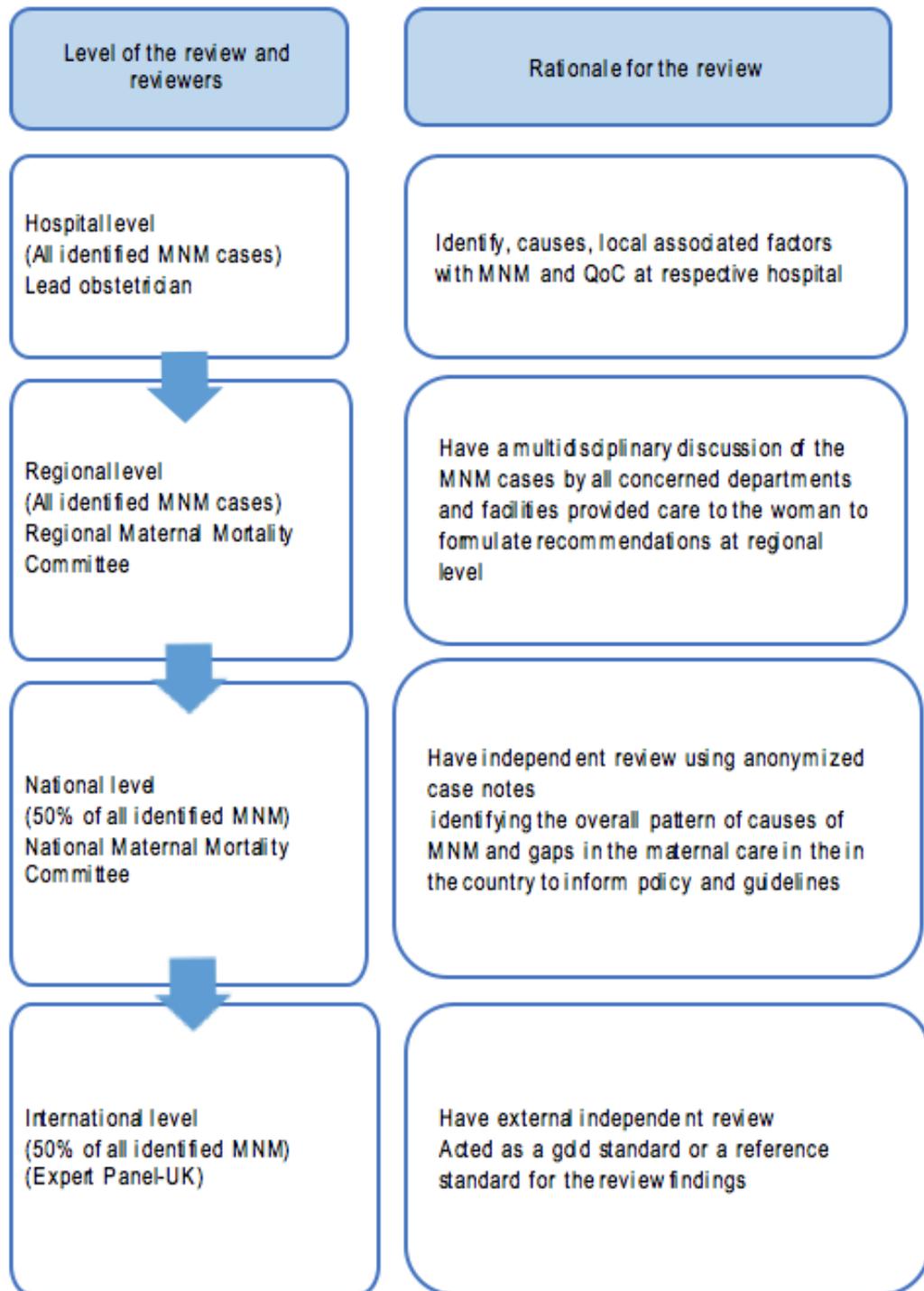


Figure 3.8: Review process for cases of MNM

#### 3.7.4.1. Hospital review

At each participating hospital, a lead trained obstetrician reviewed each MNM case after the woman was discharged from the hospital. The reviewer reviewed woman's medical file in the admitting hospital and other healthcare facilities if possible, as well as an ANC record and MNM reporting form (Form 2: Identification form for MNM).

On reviewing the case, the reviewer was advised to:

- Systematically review the chain of events before the development of the severe complication to the woman's discharge from the hospital, to examine and comment on the care the woman received before admission, referral, accessibility of the service, first assessment, diagnosis, and interventions. This review process was adopted from the International Federation of Gynaecology and Obstetrics (FIGO) guidelines and tools for maternal deaths review (De Brouwere, Zinnen and Delvaux, 2013), and previous work by Oladapo et al. (2016).
- Use root-cause analysis (RCA) of "five whys" to explore the factors contributing to the occurrence of MNM events. The RCA is a retrospective approach in exploring the key underlying (root) factors of adverse events to produce recommendations on how to rectify these factors and prevent a similar event in the future (Nicolini, Waring and Waring 2011). This study adapted the root cause analysis framework modified by Farquhar et al. (2011) for analysis of the contributing factors to maternal deaths in New Zealand and by Madzimbamuto et al. (2014) in Botswana to explore the factors associated with MNM.
- Record the findings of the review in a pre-designed form (Form 3: Assessors' form) (**Annex 5**).

#### *3.7.4.2. Regional review*

The Regional Maternal Deaths Committees comprised senior clinicians (obstetrician, family doctors, physician, staff nurse/midwife) and administrators, headed by the Director General of Health Affairs, who is the highest health official in the governorate. These committees were selected to review the MNM cases because they are well-developed multidisciplinary teams, existing since 1996 for reviewing maternal deaths to identify gaps in the health system and formulate recommendations to improve maternal healthcare.

Each MNM case was reviewed by the committee in the respective governorate. In the tertiary care hospitals in Muscat Governorate, the MNM cases were reviewed by the respective Mortality and Morbidity Committee in the hospital, similar to maternal deaths review. The hospital reviewer of MNM participated in the meeting of the committee. The committee members discussed each case systematically and they were advised to reach a consensus on the:

- Underlying cause of, contributory conditions to, and factors associated with MNM.
- Strengths and weakness in the management of the case as well as the location of the identified problems in the case management.
- Lessons to be learned from the case to prevent a similar event in future, with a specified action plan for implementing recommendations.
- Record the findings of the review in pre-designed form (Form 3: Committee form) (**Annex 6**).

#### 3.7.4.3. National review

This review was carried out by the National Maternal Mortality Committee (described in chapter 1). It differed from the previous two levels in terms of the following points:

- A sample of identified MNM cases were selected to be reviewed, as it was assumed it would be difficult and time consuming for the committees to review all identified MNM cases. Therefore, it was decided to select randomly 50% of all identified MNM from all governorates, given equal probability for each case to be selected. Stratified systematic random sampling was used to select the 50% MNM cases from all governorates. Each governorate constituted a stratum and the total identified MNM cases constituted the sample frame. The sample was selected sequentially from each governorate. All reported MNM cases within each governorate were listed in order using the admission date. Then, from each governorate, the principle investigator (PI) selected 50% of the listed cases using a sample interval of 2. The first two cases were given an equal chance to be selected. This technique ensured the cases are representative of the national and governorate levels. They also reflect the variation of admission time and cover all study period.
- The review process followed the approach of confidential enquiry, where patient medical files and other relevant documents are anonymised. The PI and the central focal person (research assistant) were responsible for the anonymisation process. The woman's name, the name of health facility, and the names of all staff members involved in her care were removed from the woman's medical records. An identification number was allocated for each woman to identify all related documents. The name of staff members was replaced by the designation, such medical office and consultant etc.

#### *3.7.4.4. International level*

The International Expert Panel consisted from healthcare professionals with previous work experience in the UK National Health Services (NHS) as well as previous experience in reviewing severe maternal morbidity and maternal deaths in the UK, including a number of reviewers of the Confidential Enquiry into Maternal Death and Morbidity in the UK. These comprised obstetricians, obstetric physicians, midwives, and anaesthetists. They reviewed the same anonymised cases reviewed by the national reviewers. Each case was reviewed by two reviewers and disagreement was resolved by a third reviewer.

### **3.8. Reporting maternal deaths and other hospital data**

For the purpose of measuring the MNM indicators, data on maternal deaths were collected from the participating hospitals using the existing maternal deaths surveillance system. The cases were reported also in the similar manner of PLTC and MNM cases. Data on the total number of deliveries and births (live births and stillbirths) were collected also from the participating hospitals to calculate these indicators (**Annex 7**). Furthermore, the total number of women registered for ANC in Oman was sought from the DoH I&S in Oman.

### **3.9. Data collection forms**

Five separate data collection forms were developed for collection of data. The development of the forms was based on data collection process, and type of data to be collected (**Table 3.6**). For fast and easy reporting of MNM cases, the form used for screening for MNM (MNM identification form (Form 2)) was digitally transferred into an MNM Reporting Application (App.). Based on our knowledge, this is the first App. for reporting severe maternal morbidity.

Table 3.6: Data collection forms

Name of the form	Purpose of the form	Description of the form	Data collected
<b>Form 1: Potentially life-threatening condition</b>	Recording details of admitted women with severe complications	Consisted of two parts: Part A: for recording details of identified cases with severe maternal complication Part B: for tracking progress of women fulfilling PLTC and MNM definition	No. cases with severe complications No. cases with PLTC and MNM Outcome of cases with PLTC and MNM
<b>Form 2: Maternal “Near-Miss” Identification Form Transferred into MNM Application</b>	Screening PLTC cases for MNM using criteria of MNM	Consisted of two parts: Part A: background information about the women, list of PLTC conditions and criteria of MNM Part B: Description of MNM event	Characterises of women with MNM Criteria of MNM Timing of occurrence of MNM event Interventions received by MNM during admission Pregnancy outcome of women with MNM
<b>Form 3: Assessor Form for MNM</b>	Recording finding of reviewers at hospital level Guiding reviewers on reviewing the MNM cases	Consisted of 13 sections: Section 1 to 3 for background information about the mother and reviewers. Section 4-13 to record the findings of the review	Causes of MNM Contributory conditions to MNM Factors associated with MNM Assessment of QoC Recommendations
<b>Form 4: Committee Form for Review of MNM</b>	Recording findings of review panels at regional, national, and international levels	Consisted of 11 sections: Section 1 to 4 for background information about the mother and the committee. Section 5-11 to record the findings of the review	Causes of MNM Contributory conditions to MNM Strengthless and weakness on the management of MNM Factors associated with MNM Assessment of QoC Recommendations
<b>Form 5: Facility Data Collection Form</b>	Collecting monthly data on births to be used in calculating the incidence of MNN and MNM indicators	Consisted of three sections: Section 1 for background information about the reporting hospital and reporting period Section 2-3 summarise the data of the reporting period	Total women given birth (deliveries) Total live births Total stillbirths Total PLTC Total MNM Total maternal deaths

### 3.9.1. MNM reporting application

The development of the App. was supported by MoH-Oman, and it followed a software development model known as “Waterfall Model” (Petersen, Wohlin and Bacca, 2009), where the PI worked with a contracted a software developer throughout the development phases and process:

**Requirement analysis phase:** a software specification document was produced that described all requirements, including the study questions and validation process to be used by the developer, as guidance in designing the software.

**Designing phase:** The structure of the reported electronic form was constructed, and all the questions in the MNM identification form (Form 2) were coded and then fine-tuned based on the review and feedback of the PI. The form was designed to be easily navigated and user-friendly. For example, the App. platform lists all the sections of the reported form at the bottom of all screens, and the icon for the reference guide is available on the top of the screen at all time. The mandatory questions were highlighted, and the questions appeared in chronological order based on the skip and validation features (**Figure 3.9**). Moreover, a verification message appeared to the user in answering certain questions.

**Testing phase:** The App. was tested internally by the developer and PI using both hypothetical and previously reported MNM. Adjustment was made based on the findings before field testing. The field testing was carried out in five participating hospitals from three different governorates for two weeks before the deployment of the software. Modifications were made according to feedback from the focal person and from the observations.

**Implementation phase:** After training, all the focal persons started using the App. in screening and reporting MNM focal persons initially for 10% of the identified cases as a quality control. After that the App. was released in the Apple store after fixing all reported problems and ensuring it is functioning as planned.

**Maintenance phase:** To ensure the quality of reported data, the performance of the App. was monitored through examining the reported data to detect any fault or problems. The focal persons were requested to report any challenges faced.

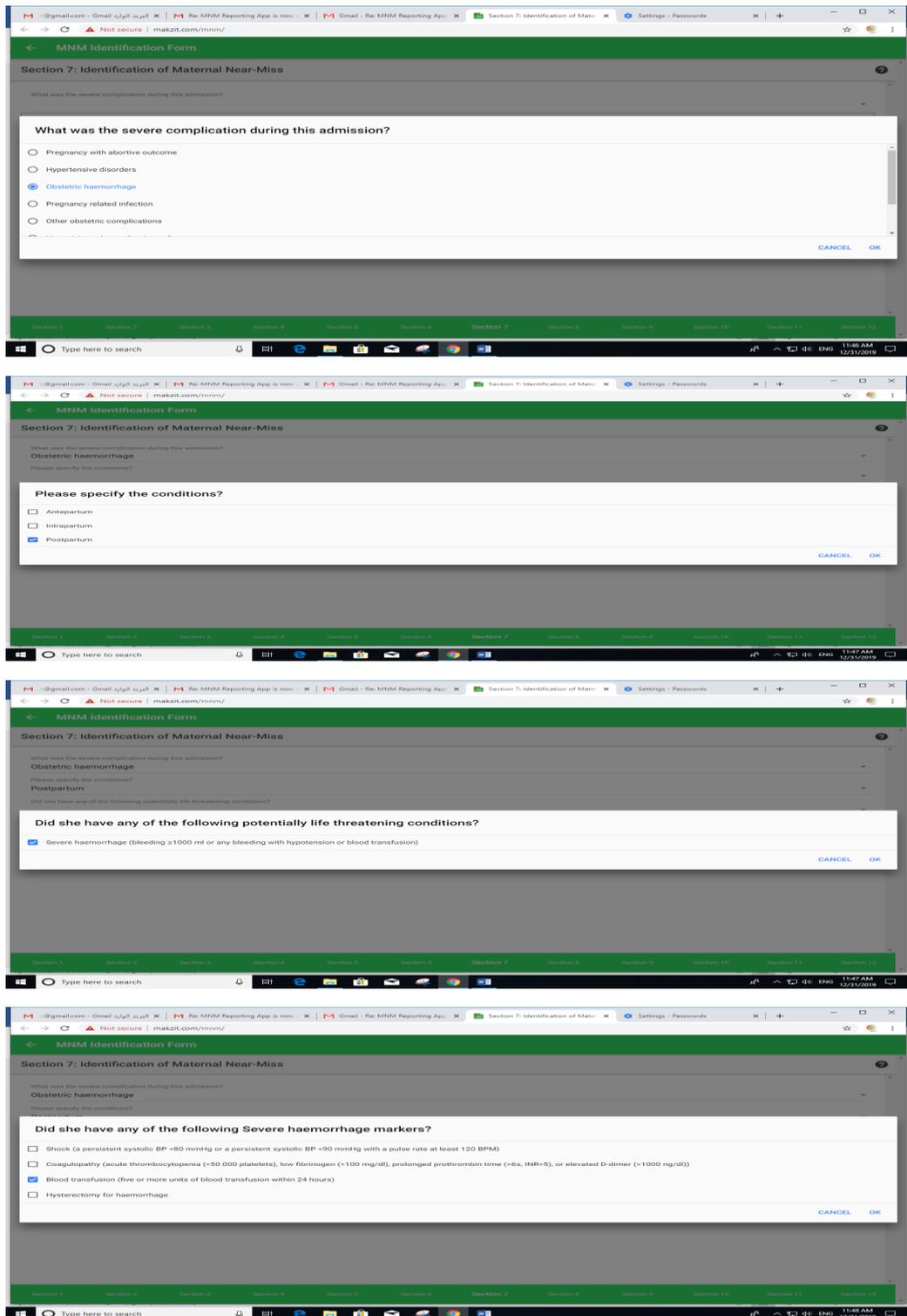


Figure 3.9: Pictorial screenshots for the MNM Application

### 3.10. Data management

The following procedures were implemented to ensure good data management.

#### 3.10.1. Data flow

A time frame was established for sending the data collection forms from the study sites to the PI (**Table 3.7**). All paper forms were either scanned and sent via email to the PI at the Liverpool School of Tropical Medicine (LSTM), or were uploaded directly into the PI OneDrive folder. A OneDrive business account was created specifically for the study, for secure electronic transfer of data from the field. A separate folder was created for each participating hospital. The MNM App. was set up to encrypt the data and send the electronic form directly to the PI's email account.

*Table 3.7: Time frame for data collection*

Form	Timing of dispatch	Responsible person
<b>Form 1: The Potentially Life-Threatening Condition</b>	Every Sunday for the previous week	Focal person in the hospital
<b>Form 2: MNM Identification Form</b>	Complete and dispatch within one week after women discharge	Focal person in the hospital
<b>Form 3: Assessors' Form for MNM</b>	Each MNM should be assessed within two weeks of discharge, and the form should be forwarded within the next week	Hospital reviewer
<b>Form 4: Committee Form for Review of MNM</b>	To be completed and dispatched within one week of the committee meeting	Committee rapporteur
<b>Form 5: Facility Data Collection Form</b>	To be completed and dispatched within the second week of the following month	Focal person in the hospital

#### 3.10.2. Tracking system

A tracking system was developed to track all identified PLTC and MNM cases, to ensure retrieval of all study forms. Thus, once the case was reported in Form 1: PLTC, the case's unique identification number was entered in the tracker, and it was followed up throughout the study process, as illustrated in (**Figure 3.10**). A unique five-digit unique identification number assigned for each identified case. The first two digits represent the study code for the participating hospital, and the remaining three digits were the serial identification number of the cases in the reporting hospital. This identification number was used in all the forms, as in the case of MNM. This facilitated communication between the study team in tracking the cases and study forms, and preventing data loss.

FacilityCode-ID	Type of Form	Form Received (Y/N)	Paper or EDC	Month & Year of Admission	Form Checked	NM or PLTC	Form Info	Able to Process. Y/N	Date Processed and Formic Exported + Initials	Cleaning Status	Queries Sent	Queries acknowledged	Queries Returned	Queries Updated	Comments
01_001	Maternal Near-Miss														
	Assessor Form														
	Regional Committee Form														
	National Committee														
	Expert Form														
01_002	Maternal Near-Miss														
	Assessor Form														
	Regional Committee Form														
	National Committee														
	Expert Form														

Figure 3.10: Tracking system for identified cases of MNM

### 3.10.3. Verification and cleaning of data

To ensure the accuracy of data, received data were cross-checked either between different forms or with the MoH registers (Table 3.8). Furthermore, during supervisory visits, with the permission of the authorities in the hospital, the PI examined 10.0% of each hospital's discharge data from the department of obstetrics and gynaecology to ensure that there were no missing cases of PLTC and MNM, and to verify that the reported cases fulfilled the definition of PLTC and MNM. This procedure revealed very few PLTC cases were missing in some facilities (1-2 cases), but not MNM. These identified cases were reported later.

Table 3.8: Verification of collected data

Data	Verified with
Number of reported MNM and PLTC in Form 2: MNM identification form	Recorded number in Form 1: Potentially Life-threatening Condition and Form 5: Facility Data Collection Form Hospital discharge data
Recorded data for women with PLTC and MNM	Patient medical file
Number of maternal deaths in Form 2: MNM identification form	National maternal deaths notification system
Total number of deliveries, live births, stillbirths and multiple births	Birth and Death Register, with assistance from statisticians in each hospital

The data was processed by research assistants and extracted to Excel spread sheets for cleaning, using a cleaning guideline developed for this purpose. The quality of data was assessed to ensure the data is correct and consistent. The PI and the research assistant cleaned the data by:

- i) identifying errors and corruptions in the data and correcting them.
- ii) reviewing the data to identify missing variables.

The majority of discovered missing variables or suspicious variables were resolved by contacting the focal persons in the respective hospital to check the medical record of the case case. Furthermore, supervisory visit was utilised to complete missing data or checking suspicious variables.

#### **3.10.4. Data storage**

As explained earlier, all collected data was transferred digitally to PI. All the study forms and the data were stored in PI LSTM OneDrive on a password-protected personal computer.

### **3.11. Quality assurance and control**

Quality assurance and quality control determine the integrity of the results and the conclusions of the study. Quality assurance refers to the measures taken before data collection, while quality control concerns activities implemented during and after data collection (Gassman et al., 1995; Knatterud et al., 1998; Whitney, Lind and Wahl, 1998). **Figure 3.11** lists the quality assurance and control procedures used in this study.

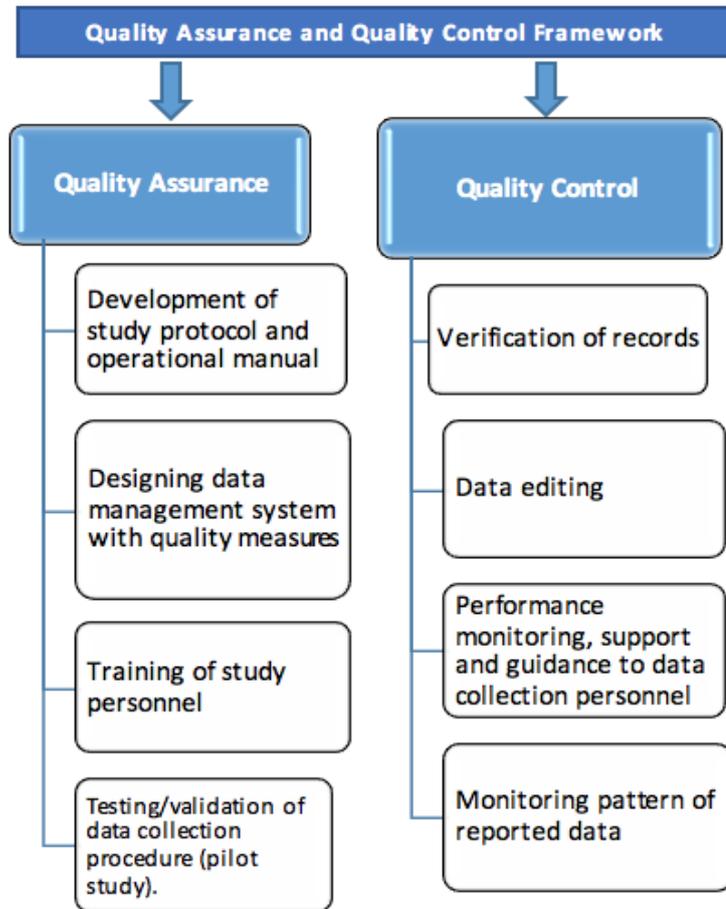


Figure 3.11: Quality assurance and control procedures

### 3.11.1. Quality assurance

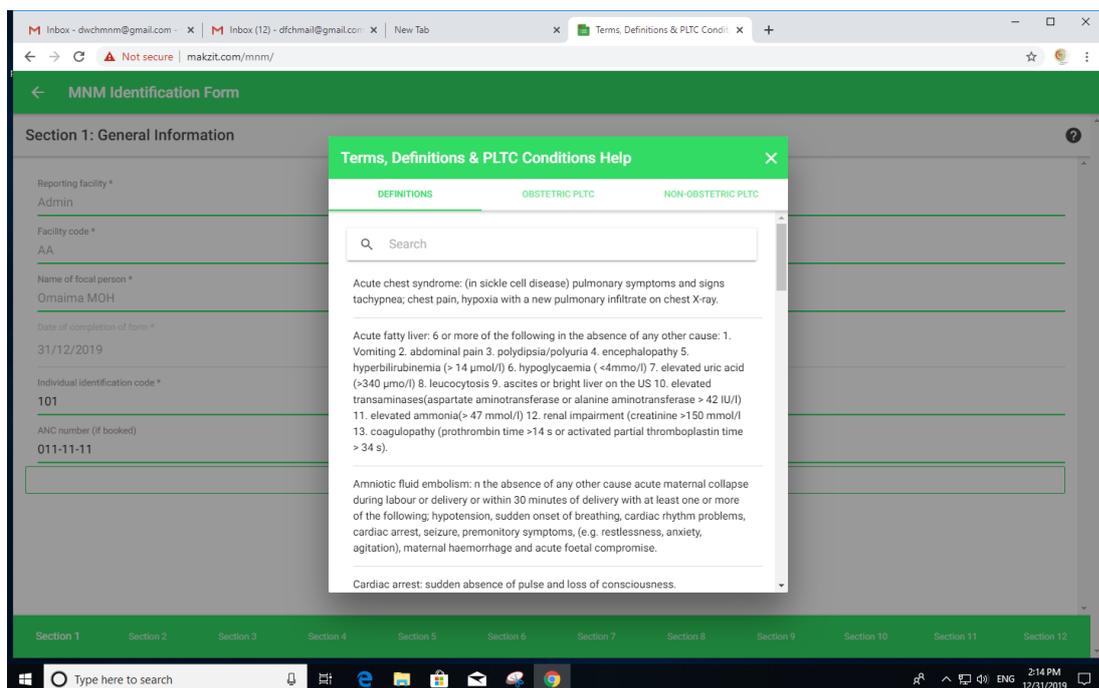
#### 3.11.1.1. Study protocol and study manual

A study protocol was developed and reviewed by external international and national experts. To ascertain that data collection was consistent across all participating hospitals, the protocol was translated into an operational manual, which acted as a reference document containing details of all data collection procedures and data collection forms. It also described the study organisation and responsibility of different study personnel, to ensure accomplishment of study tasks and smooth communication between different personnel.

#### 3.11.1.2. Setting up a data management system with quality measures

Several measures were integrated into the data collection system to reduce human errors in reporting of cases and processing of data, as listed below.

- *Reporting of cases*
- The Unique Antenatal Care (ANC) Registration number for the woman and the name of parent institution were entered in the study forms to avoid duplication of reporting and to recognise if a woman had more than one admission with an MNM event during the same pregnancy.
- Form 2: MNM identification form included definition and values for MNM criteria for the focal person to easy referral for a focal person. The same were included in the MNM reporting App.
- The MNM App. replaced the paper Form 2: MNM identification. It was designed with a set of skips and validation rules to increase the accuracy of the reported data. Moreover, it includes a list of the PTLC and all the definitions of PTLC and MNM markers as a reference guide (**Figure 3.12**). It has a user manual that describes the process of reporting of cases. It works offline and can be used in multiple different electronic devices, including mobile phones, iPads and desktops. The app allows the user to complete the reporting as one go or save it as a draft to return to later. Once the form is completed, it can be saved and stored in the save folder.



*Figure 3.12: The Reference guide for the definitions of conditions and MNM criteria in the MNM application*

- *Processing of data*
- The paper data collection forms were designed in Formic format to overcome human data entry errors, as the data were exported directly from the forms to Excel sheet. Formic is an optical recognition software that reads handwritten or typed information from scanned images.
- The data from the MNM App. was exported as an Excel file and in PDF form. The Excel file was used to extract and process the data, while the PDF file was used by the reviewers in reviewing the MNM cases.

### 3.11.1.3. *Orientation and training on the study process and tools*

Preceding the data collection phase, orientation meetings were organised with the key stakeholders at the national and governorate levels to introduce the study. The PI visited all the governorates (n = 11) in Oman, and held a series of meetings with the highest official stakeholders in each governorate. Staff in the departments of obstetrics and gynaecology were oriented in the study process and recording of women with severe maternal morbidity. Focal persons were requested to conduct an orientation session about the study for staff members in their respective hospitals using a standard pre-prepared presentation.

All the study personnel were trained in data collection procedures using real-life cases from Oman. All trainings were conducted by PI, with assistance from senior trainers from the Centre for Maternal and New-born Health (UK) and the MoH in Oman.

*Table 3.9: Description of training workshops on data collection process*

Target group	Name of training and timing	Purpose and description of the training
<b>Focal person</b>	National workshop on identification of MNM for one day on May 2016	Introducing the focal persons to the study procedures and data collection instruments
	One day training workshop in each participating hospital between July to August 2016	Practical training on participating hospitals on using study manual, recording of severe maternal morbidity, screening, and reporting MNM
	A one-day national practical training workshop on using MNM App. on February 2017	Introducing the MNM App. and practical training on using it for screening and reporting MNM cases
<b>Reviewers</b>	A national training workshop on reviewing	Introducing the concept of near-miss, principles and guidance on reviewing maternal deaths and MNM
	A two-day national workshop on reviewing MNM on October 2017	Strengthening skills on reviewing MNM cases; identifying the underlying causes, contributory conditions and associated factors; assessing the QoC and formulating learning lessons for future improvement of QoC

#### 3.11.1.4. Testing of data collection procedures and tools (pilot study)

- *Study site and period*

A pilot study was conducted for one month (July-August 2016) to test:

- Data collection process (screening, reporting, and review of MNM cases including the MNM criteria and PLTC list) under the actual study conditions
- Data collection forms
- Instruction manual

Three governorates from different locations (Muscat, Dhaklia, and North Sharqia) were used for testing. Eight facilities were selected to represent all categories of the participating hospitals (primary district hospital, regional secondary hospital, and tertiary care hospital).

- *Results of the pilot study*

Reported cases: 18 reported cases fulfilled the definition and criteria of PLTC (**Table 3.10**), of which 11 were MNM. There were no maternal deaths during the study period. The majority (7/11) of MNM cases were reported from the tertiary hospital (code-01), which is the biggest tertiary referral hospital receiving cases from all over the country. However, the hospital reported only MNM without PLTC, because of a shortage of staff and increased workload due to field testing being conducted during the summer. In addition, there was a period during which the focal person was on emergency leave. Based on that, it was decided to recruit at least two focal persons per hospital.

*Table 3.10: Pilot study results*

Hospital code	Category of hospital	Total deliveries	Total reported PLTC	Total reported MNM	Total reported maternal deaths
01	Tertiary	806	NA	7	0
02	Secondary	400	1	0	0
03	Tertiary	385	3	2	0
12	Secondary	503	8		0
13	District	59	0	0	0
14	District	124	0	0	0
15	Secondary	270	1	1	0
16	District	176	5	1	0
<b>Total</b>		2,723	18	11	0

- *Feedback and observation on the study manual, forms, and data collection process*

An evaluation form was designed to record feedback from staff on both study manual and forms. In addition, the PI examined the completed forms, and based on

the observations a number of questions regarding the assessment of QoC in the assessors and committee forms were modified to be more specific. **Table 3.11** lists the main observations noted and actions taken

*Table 3.11: Observations and action taken based on the pilot study*

Area	Observations	Action taken
<b>Focal person</b>	Having one focal person per hospital was not enough, especially in large hospitals If the focal person was on leave, the screening and reporting processes would be affected	The number of focal persons per hospitals was increased
<b>Instruction manual</b>	It is a clear document. No modification suggested	No action taken
<b>Data collection process</b>	No suggestion made in the screening process Suggested to develop electronic data collection tool for reporting MNM cases	No change was made in the process MNM App. was developed
<b>Study forms</b>	Form 2: MNM identification form A number of questions need to be made clearer and more specific, related to: Previous complications Previous admission To add the values of laboratory tests in the MNM criteria To add definition of PLTC conditions in the form To modify the definition of severe haemorrhage to include drop in HB To change the section of foetal outcome to neonatal outcome	The questions were modified to be clearer and definitions were added. The additional PLTC conditions and comments on MNM criteria were presented earlier under section 3.6.1 Development of MNM criteria)
	Assessors' and Committee forms: The reviewers did not comment on some aspects of care the woman received like pre-admission, referral etc.	The forms were modified, and specific questions were added to address different aspects of patient management

### 3.11.2. Quality control

Verification of records and data editing were described before under data management

#### 3.11.2.1. Performance monitoring, support and guidance to data collection personnel

Monitoring performance and support to data collection personnel were done through the following mechanisms.

- *Supervisory visits*

Each participating hospital was visited at least two times during the data collection phase and once during the preparatory phase. Some hospitals required more visits based on the number of reported cases and the identified problems during the previous visit. The objectives of the visits were:

- To identify any deviation from the protocol and need for retraining and support

- To validate the reported data during these visits as described above under verification and cleaning of data.
- Ensure the smooth running of the study and supporting focal persons through resolving any challenges they faced in data collection by discussing the challenges with the concerned authorities in the hospital.
- *Maintaining good communication channels*

Communication is a key tool to ensure tasks are accomplished and problems addressed promptly. It can be a challenge in a multi-centre study. Thus, in addition to the communication by email and phone calls, the PI maintained direct communication with the individual data collection personnel by utilising WhatsApp messenger (via smartphone) to receive and respond immediately to any queries from the field. This was done through individual communication or through the discussion forum created for this purpose.

- *Monitoring pattern of reported data*

The number, percentage, and diagnosis of reported cases was monitored and compared between months to discover underreporting or deviation from the average expected figures.

### **3.12. Analysis**

Data were analysed based on the research questions using IBM SPSS version 24 (**Table 3.12**). In addition, characteristics of MNM were described and compared with PLTC.

#### **3.12.1. Characteristics of MNM**

Characteristics of MNM including socio-demographic, reproductive, and characteristics of index pregnancy data were analysed using descriptive and inferential statistics. Continuous data were summarised using means with standard deviations (SD) and categorical data using proportions. 95% confidence interval (CI) were used for both data. Data of age, gravida, parity, and timing of booking for ANC were stratified to explore the differences between the categories of each variable.

Furthermore, the characteristics of women with MNM were compared with those of women with PLTC to explore differences and thus possible risk factors for MNM. Pearson's chi-squared test was used for categorical variables, and analysis of variance (ANOVA) to test differences means of continuous variables. Logistic

regression was used to control for confounders. For all tests, statistical significance was determined at  $p < 0.05$ .

Table 3.12: Analysis framework for the study

Research question	Analysis	Variables and data source
<b>What is the incidence of maternal “near-miss” in Oman? What are the values of MNM indicators for Oman?</b>	PLTC incidence per 1,000 women giving birth PLTC incidence per 1,000 ANC registered women MNM incidence per 1,000 women giving birth MNM incidence per 1,000 ANC registered women PLTC to MNM ratio MNM ratio per 1,000 live births SMO ratio per 1,000 live births Mortality index MNM mortality ratio Case fatality rate Stillbirths rate	Reported PLTC, MNM and maternal deaths Total number of women giving birth in the participating hospitals, total number of live births, and the total number of stillbirths in recorded in Facility Data Collection Form Total number of women registered for ANC
<b>What are the causes of MNM?</b>	Descriptive frequencies of causes of MNM per ICD-MM groups and specific causes as: Reported by healthcare providers Assigned by reviewers at hospital, regional, national and international levels Comparing causes of MNM assigned by the four review panels Level of agreement between the review panels in assigning cause of MNM Comparing causes of MNM with those of PLTC and maternal deaths Descriptive of the causes MNM reported by healthcare providers in relation to: Criteria used in reporting these causes Timing of occurrence of MNM in relation to pregnancy Reporting hospitals Interventions received by mothers with MNM (blood transfusion, surgery, admission to HDU and ICU) Pregnancy outcome for mothers with MNM	Causes of MNM recorded in the MNM Identification, Assessor, and Committee forms Interventions received by women with MNM recorded in MNM identification form Pregnancy outcome of MNM recorded in MNM
<b>What are the contributory conditions to MNM?</b>	Descriptive frequencies of contributory conditions to MNM (maternal conditions, related to foetus, related to interventions) in total and per underlying cause as assigned by reviewers at the hospital, regional, national and international levels Comparing contributory conditions to MNM identified by the four review panels	Contributory conditions to MNM recorded in the Assessor and Committee forms

Research question	Analysis	Variables and data source
<b>What is the standard of care the women with MNM received?</b>	<p>Descriptive frequencies of standard of care (good care, improvement in QoC identified but make no difference to the outcome, improvement in QoC identified which might have made a difference to the outcome) in total and per underlying cause assigned by reviewers at the hospital, regional, national, and international levels</p> <p>Comparing the standard of care assigned by the four review panels</p> <p>Level of agreement between the review panels in assigning standard of care</p>	<p>Assessment of QoC by reviewers as recorded in the Assessor and Committee forms</p>
<b>What are the factors associated with MNM events?</b>	<p>Descriptive frequencies of factors associated with MNM (organisation of care, healthcare team, woman) in total and per underlying cause as identified by reviewers at the hospital, regional, national and international levels</p> <p>Comparing causes of MNM assigned by the four review panels</p>	<p>Factors associated with MNM by reviewers as recorded in the Assessor and Committee forms</p>

### 3.12.2. Estimating the incidence of MNM and MNM indicators

The incidence of MNM was estimated using the data of total live births and women giving birth collected from the participating hospitals during the study period. **Table 3.13** illustrates the formulae used in calculating the incidence of MNM and selected MNM indications.

*Table 3.13: Formulae for estimating incidence of MNM and MNM indicators*

Indicator	Definition
Incidence of PLTC (per 1,000 women giving birth)	Total PLTC/ total women giving birth x 1,000
Incidence of MNM (per 1,000 women giving birth)	Total MNM/ total women giving birth x 1,000
PLTC to MNM ratio	Total PLTC/ total MNM
MNM ratio (per 1000 live births)	Total MNM/ total live births x 1,000
SMO ratio (per 1000 live births)	(Total MNM + total MD) per 1000 live births
MNM ratio (per 1000 live births)	Total MNM cases/ 1000 live births
MNM mortality ratio	Total MNM/ total MD
Mortality index	Total MNM/ (total MNM + total MD) x 100
Stillbirth rate per 1,000 birth	Total stillbirth/ (total stillbirths + total live births) x 1,000

### 3.12.3. Measuring the level of agreement

The level of agreement between panels of reviewers was measured using Cohen's kappa coefficient ( $\kappa$ ). The study used the Kappa values proposed by Landis and Koch (1977) (**Table 3.14**).

*Table 3.14: Interpretation of kappa coefficient value*

kappa	Strength of agreement
$\leq 0$	Poor
0.01-0.20	Slight
0.21-0.40	Fair
0.41-0.60	Moderate
0.61-0.80	Substantial
0.81-1.0	Almost perfect

## 3.13. Ethical considerations

### 3.13.1. Approval from ethics committees

The study was approved by both the ethics committee of Liverpool School of Tropical Medicine (Institute of the PI) and the Research, Ethical Review and Approval Committee in MoH-Oman (**Annex 8**). The use of OneDrive for electronic transfer of data was approved by the LSTM Scientific Computing Committee.

### **3.13.2. Obtaining informed consent**

For this study, it was not considered appropriate to seek consent from the women themselves for the following reasons.

The review of MNM was integrated into the existing maternal deaths review system, which has been in place since 1992. The maternal deaths review is regulated by the Ministerial Decree issued in 1992 on forming maternal review committee (the last amendment was made to the Decree was in 2015; Ministerial Decree 2/ 2015). The Decree gives permission to the Committees to review women's medical files for the public benefit to improve QoC. The case file of MNM cases were treated in a similar manner as files of maternal deaths and were reviewed by the same reviewers. Thus, the MNM review was operated and regulated by the Ministerial Decree that regulates maternal deaths review. The plan was the two reviews (maternal deaths review and MNM review) will be running together under one umbrella of regulation and operation.

The study was considered as an audit of severe maternal morbidity in which there was no direct contact or interview with women or their families. Data were extracted from women's medical files, and an individual form was completed after woman's discharge from the hospital.

As stated in the WHO document *Beyond the Numbers: Reviewing maternal deaths and complications to make pregnancy safer*, asking for consent can cause women concern regarding the QoC they received, which can cause psychological harm and threaten the health system (WHO, 2004). In Oman before the study, many hospitals were reviewing some of the MNM cases as part of hospital audit of severe maternal complications. Also, it was expected that the woman understands that some of their information can be shared within healthcare facilities to provide them with better care.

### **3.13.3. Confidentiality**

According to the NHS Code of Practice (Department of Health (UK), 2003), confidentiality means that patients' identifiable personal and medical information is kept private, and is not disclosed or used without their permission, except for their healthcare, legal justification or for justified public interest. Anonymised information

is considered not confidential, and may be used with some restrictions. The following measures were implemented to protect the confidentiality of participants:

- *Incorporation of the study into the existing maternal deaths review system*

The study followed the same guidance and principles of maternal deaths review under the Ministerial Decree of Maternal Deaths Review, according to which it is mandatory to maintain confidentiality throughout all processes and discussions of the review, and information should not be disclosed. The same members of the national and regional committees reviewed the MNM cases. Maintaining confidentiality was addressed also in reviewers training workshops.

- *Using an identification number*

The woman's data was protected further by using study identification numbers in all data collection forms. Woman's identifiable information, such as name, hospital number, and ANC number were recorded only in Form 1: Potentiality Life Threatening Condition. This form was used by treating staff and kept in the individual hospital. When required PI used this form for tracking women if they were referred to another hospital to avoid duplication. After reviewing the form, the PI anonymised the all personal details in the form.

- *Ensuring anonymity*

Anonymisation means removal of identified patient information such age name, date of birth, and address (NHS, 2003). In this study, all woman's documents were anonymised before the review by the National Maternal Death Committee and International Expert Panel. The research assistant at the MoH with PI were responsible for the anonymisation process. The women's names, names of health facilities, and the names of all staff involved in care cases were removed from each woman's medical records. Subsequently, the study identification number for each case was used to identify all related documents. After anonymisation, the medical files were encrypted and uploaded to the PI LSTM OneDrive account for the international expert panel review. The PI prepared and circulated copies of the files for the panel members. All hard copies were kept in secure cabinet, and were shredded after completing the review process.

- *Local factors*

It was not feasible to implement the same system to anonymise medical files for the hospital review and Regional Maternal Mortality Review because of the shortage of human resources at the local level. Secondly, the number of maternal deaths and

severe maternal morbidities is relatively small in individual governorates, and such cases would be well known in small communities, which means that the name of healthcare facility and the clinicians and even the woman could be identified. Furthermore, the aim of the local review was to identify local factors, and such information is important. All the reviewers at the two levels were reviewers of maternal deaths cases, and they followed the regulations of the maternal deaths review system explained earlier.

- *Use of electronic data collection tool and transfer*

Each participating hospital was allocated an individually numbered iPad with a separate set of security codes. The focal persons were requested to keep the passcode secure. In addition, each focal person was provided with a username and password to use in reporting the identified cases. The data was encrypted from the App. and sent directly to the PI LSTM email.

Use of OneDrive was approved by the LSTM Scientific Computing Committee. An account was created for the PI under the LSTM Umbrella. Within that account the PI created a folder for each hospital which was shared with the focal persons in those hospitals and with the national research assistant in the MoH. Focal persons uploaded the study form in their respective folder. The data was encrypted immediately from their devices and throughout the transitional phase to PI device. Focal persons were able only to access their own hospital folders.

#### **3.13.4. Dealing with staff misconduct and malpractice**

Issues of staff misconduct in Oman are managed via a separate and mutually exclusive system, it was crucial to keep both systems separate to ensure the participation of healthcare providers in the identification and review process. A similar system operates in countries (e.g. South Africa and the UK) with long-standing experience with maternal death reviews and MNM reviews (Knight et al., 2014b; Moodly et al.2014). The MNM review is based on using the “no blame, no shame” approach, which encourages the identification of potential errors or malpractice in order to address systemic issues, avoiding the concealment or omission of such data by health professionals due to the fear of reprisals. Although it was not mandatory for the PI to report such incidents, a plan was in place in case any serious misconduct or adverse serious events were found, whereby it would be explored whether such events were addressed by the respective Hospital Mortality and Morbidity Committee. If not, the findings could be brought to the policy maker’s attention without referring to or identifying individual staff members involved. This is

similar to current procedure under UK Confidential Enquiry of Maternal Mortality and Morbidity (Knight et al, 2014b). During the study period, it was not found necessary to use the plan with any event.

### **3.14. Positionality in research**

Positionality refers to the researcher's position in relation to the study and delineating, the implication of this position on all aspects of the research (Foot and Batell, 2011). Positionality is shaped by the researcher's background and experiences that affect the study process, interpretation of the findings, and conclusions drawn.

As researchers, we are requested to be conscious and describe our positionality and biases explicitly through a reflective process. Savin-Baden and Howell Major (2013) described three areas that researcher is requested to reflect on:

- Location to the subject area, in which researchers acknowledges their personal position and its potential to influence the research.
- Positionality in relation to the research context and process.
- Participants – position in relation to the study participants.

Reflecting on the above as a PI, my positionality has a positive influence in research from the conception of the idea of the research, selection of the study process and implementation.

#### **3.14.1. Location to the research or subject area**

The idea of the research evolves from my position as a previous Director of the Department of Woman and Child Health in MoH-Oman, and a member of the National Maternal Mortality Committee. Based on the findings of evaluation of Maternal Deaths Surveillance System in Oman, and analysis of maternal deaths, I considered examining and developing additional assessment instruments related to QoC by looking into the MNM cases. I believed a great deal could be ascertained by looking into these cases of severe morbidity to complement the national review of maternal deaths.

My previous position facilitated the planning process and sourcing support for the study. I was able to gather background data about study setting that facilitated the planning process. At the preparation phase of the study, I shared the idea of the research with concerned stakeholders in the MoH. There was a common interest in

conducting the research for me as a researcher and the stakeholders in the country to implement an MNM review, as it was expected that the study would assist in strengthening maternal surveillance system to improve the QoC. I succeeded in getting the National Maternal Mortality Review Committee on board with the study as reviewers. Furthermore, I visited all 11 governorates in the country to secure support for the study and met stakeholders in these governorates, including director generals of health services, and directors and heads of woman and child health sections, participating hospitals, obstetrics and gynaecology departments, and other staff members in these departments.

The MoH adopted the idea of the study of introducing MNM and included it in its strategic five-year-plan for health for the year 2015-2019, along with the activity of strengthening the system of maternal deaths' review and response. Furthermore, the UNFPA and WHO office in Oman expressed their willingness to support the study.

I considered this as an achievement for the study, because experience shows that implementing a successful national review requires governmental support, leadership, and involvement of stakeholders within a matrix of professional understanding and participation (Bhattacharyya, Srivastava, and Knight 2014; Kurinczuk et al., 2014; Lewis, 2014). Secondly, stakeholder participation increases ownership of a project and opportunities for action in response to findings.

Coming from a background of obstetrics and maternal health was an enabling factor in understanding the related literature and developing the MNM criteria. Furthermore, it facilitated the process of communication and discussion of the cases with focal persons when they had queries. My expectation of care could have affected the interpretation of QoC the women received. However, the QoC was assessed by reviewers without my influence, and interpretations were supported by literature.

### **3.14.2. Positionality in relation to research context and process**

Familiarity with the setting in Oman and characteristics of the healthcare facilities facilitated the selection of the participating hospitals. It also assisted in predicting the challenges that could face the research and planning to overcome them. Knowing the structure and hierarchy of the health system in Oman assisted in planning the review process of the MNM. Taking into consideration my previous position, and to eliminate potential biases in the review process, I did not participate in reviewing

MNM cases either in Oman or in the UK. However, the effect of such positionality in interpreting the findings of the review cannot be eliminated. It is expected such effect may be minimal, given the fact that the results are supported by figures and facts.

### **3.14.3. Participants**

There was no influence of my positionality on the study participants, as all data were collected from patients' medical record. However, one can argue that my position could affect the reporting process and review, as the staff members at the participating hospitals might feel discomfort and worried that the findings of the review can be disclosed or used against them if mismanagement was discovered. However, the study design anticipated that anonymisation of all patient records, including the management team, minimised this threat.

### **3.15. Summary**

This chapter has described the study methodology, including the study site and approach used to achieve the study objectives. The study was a prospective cross-sectional study that combined survey with in-depth review of identified cases. Cases were recruited from 23 hospitals, including public and private hospitals conducting more than 90.0% of the total deliveries in the country. The study used MNM identification criteria developed based on the WHO application of ICD-10 to deaths during pregnancy, childbirth, and puerperium: ICD MM. Cases were recruited from the participating hospitals over 12 months to account for seasonal variation. In-depth review of identified MNM cases was carried out sequentially by four panels at the hospital, regional, national, and international levels. All cases were reviewed at the hospital level, followed by regional review. 50.0% of the identified cases were selected by systematic sampling for national and international review panels. Data quality was ensured through training of focal persons and reviewers, supervisory visits, and validation of data. Results were analysed based on the stated research questions using SPSS version 24.

### **3.16. Overview of results chapters**

The results are presented in five chapters following the structure of the objectives of the study (based on the research questions), as explained in chapter 1:

- To determine the incidence of MNM and the MNM indicators for Oman.

- To identify the underlying causes of, and contributory conditions to MNM.
- To assess the quality of care for women with MNM, and to identify priority areas for which improvements could be made.
- To identify the factors associated with MNM (organisational, the medical team and the woman herself).

These objectives are addressed in the following chapters as described below.

**Chapter 4 reports on objective 1:** Presents the total births in the participating hospitals, and the total number of reported cases of PLTC, MNM, and maternal deaths, along with the incidence of MNM and other MNM indicators for Oman. Describes socio-demographic and reproductive characteristics of women with MNM.

**Chapter 5 reports on objective 2:** Reports the underlying causes of MNM as assigned by healthcare providers, with a description of the criteria used for identification of these causes. Describes MNM events and the interventions received by mothers with MNM *as per* the underlying causes.

**Chapter 6 reports on objective 2:** Presents the findings of the MNM reviews conducted at four different levels. Specifically describes and compares causes of, and contributory conditions to MNM, as assessed by the review committees.

**Chapter 7 reports on objectives 3 and 4:** Presents the findings related to the assessment of the QoC with MNM received, and factors associated with MNM events are presented.

Table 3.15: Overview of the presentation of the study results

Research question	Chapter	Description of contents
<b>Research Q1: What is the incidence of maternal “near-miss” in Oman? What is the MNM ratio, SMO ratio and mortality index for Oman?</b>	Chapter 4: Characteristics and Indicators of MNM (MNM indicators for Oman, incidence, and characteristics of women with MNM)	The identification of potential life-threatening conditions, MNM and maternal deaths. The incidence of MNM and MNM indicators for Oman Characteristics of women with MNM with a comparison with those of PLTC: - Socio-demographic - Reproductive characteristics - Characteristics of the index pregnancy
<b>Research Q2: What are the underlying causes of MNM?</b>	Chapter 5: Underlying Causes of MNM, Identification Criteria, and Description of events	Underlying causes of MNM as reported by health providers Identification criteria for MNM Distribution of causes of MNM by the timing of MNM events Distribution of causes of MNM by type of reporting hospitals Causes of MNM and interventions received by mothers with MNM Causes of MNM and pregnancy outcome for mothers with MNM
<b>Research Q3: What are the contributory conditions to MNM?</b>	Chapter 6: Comparison of Causes of and Conditions Contributing to MNM According to Review Committees	The underlying cause of MNM as assigned by: - Assessors at the facility level. - Regional Maternal Mortality Committee - National Maternal Mortality Committee - International Expert Panel Level of agreement between the four levels of reviews regarding the underlying causes of MNM Contributory conditions for MNM as identified by the four levels of reviews Comparison of the contributory conditions identified by the four levels of reviews
<b>Research Q4: What is the standard of care the women with MNM received? Research Q5: What are the factors associated with MNM events?</b>	Chapter 7: Quality of Care and Associated Factors in MNM	Assessment of quality of care as assigned by the - Assessors at the facility level - Regional Maternal Mortality Committee - National Maternal Mortality Committee - International Expert Panel Factors associated with MNM identified by different reviews: - Factors related to organisation of care - Factors related to the health team - Factors related to the woman herself Comparison of identified associated factors by different reviews

## 4. Characteristics and Indicators of MNM

**This chapter is divided into four sections:**

The first section presents the total births, reported, included and excluded cases of PLTC, MNM, and maternal deaths identified in the participating hospitals during the study period. Section two reports the incidence of MNM and other MNM indicators. The characteristics of women with MNM are described and compared with those with PLTC in section three. Finally, section four summarises the findings presented in the whole chapter.

**The chapter focuses on answering the following research questions:**

- What is the incidence of MNM in Oman?
- What is the MNM ratio, severe maternal outcome ratio and mortality index for Oman?

### 4.1. Identification of PLTC, MNM, and maternal deaths

Each study hospital completed a 12-month survey between October 2016 and September 2017. During the study period, a total of 90,968 women were registered in the ANC clinics across Oman, 78,446 women gave birth in the 23 participating hospitals, resulting in 78,918 live births and 537 stillbirths (**Annex 9**). Of the women admitted during pregnancy, childbirth, and the postpartum period in the 23 participating hospitals, a total of 1,778 pregnancies were identified as having potentially life-threatening conditions, of which 19% ( $n = 332/1,778$ ) were reported as MNM and 81% ( $1,446/1,778$ ) as PLTC. There were 27 deaths during pregnancy, childbirth, and puerperium reported during the same period from these hospitals.

#### 4.1.1. Reported women with PLTC

A review of the 1,446 reported cases of PLTC, 2.8% ( $n = 41$ ) cases did not meet the criteria and were excluded. Three cases were due to road traffic accidents were further excluded. A description of the excluded cases with reasons for exclusion is presented in (**Annex 10**).

#### **4.1.2. Reported women with MNM**

Out of the 332 reported cases of MNM, after review, 5.1% (n = 17) did not meet the criteria and were excluded (re-classified as PLTC). Of the 315 MNM cases, two were further excluded because they were due to accidental causes (road traffic accident and severe burn injuries). Of the remaining 313 cases, one woman had two “near-miss” events resulting in a total of 313 MNM events and 312 MNM cases.

#### **4.1.3. Maternal deaths**

Out of the 27 reported deaths in women who were pregnant or had given birth, one death was due to a road traffic accident, and one was a late maternal death (a woman died after 42 days following termination of pregnancy), leaving 25 maternal deaths (MD) that were included in the study.

In summary, the total included cases in the study were 1,419 PLTC, 312 MNM, and 25 maternal deaths (**Figure 4.1**). These figures were used to calculate the incidence of MNM and MNM indicators for Oman presented in section 4.2.

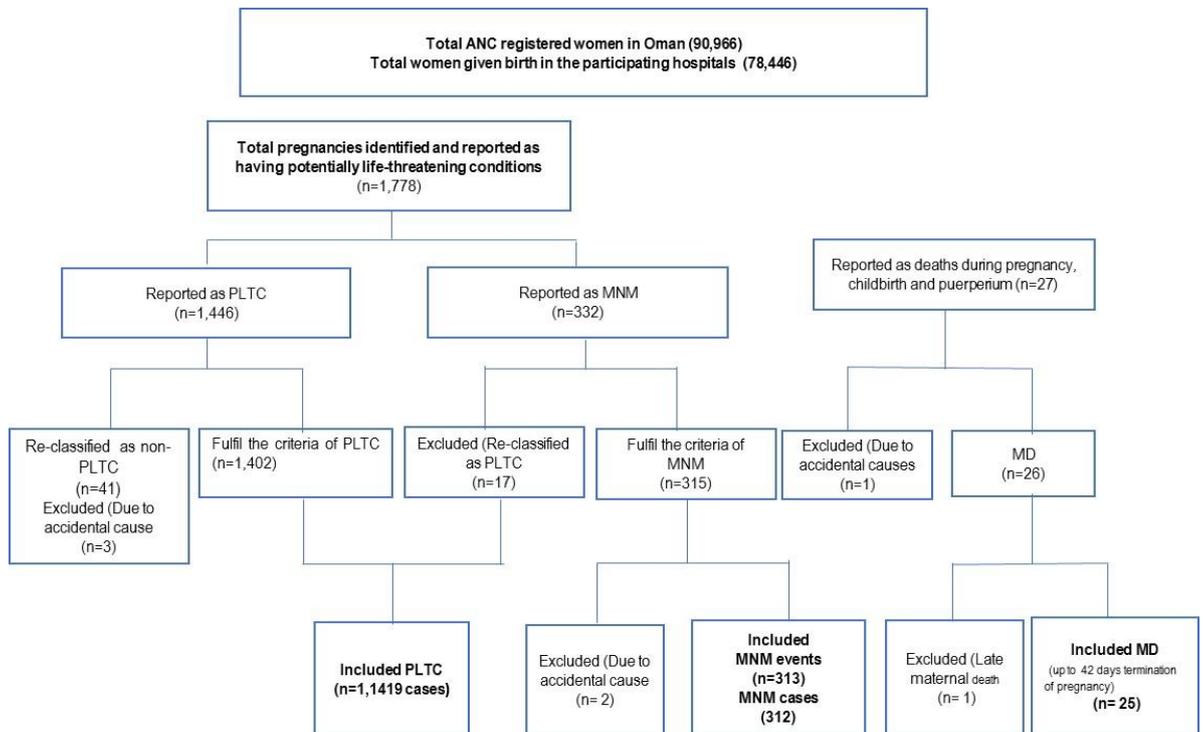


Figure 4.1: Reported, included and excluded cases of potentially life-threatening conditions, MNM and maternal deaths in the study over a period of 12 months

#### 4.1.4. Reported PLTC, MNM and MD by month

A slight variation was observed in the distribution of the reported cases of PLTC, MNM and MD as well as the total women given births in the participated hospitals per month (Table 4.1). Furthermore, it seems there was no relationship between the birth rate and the total reported cases of PLTC, MNM and MD. The highest births rate was recorded in August (9.1%, n= 7,121) and October (9.1%,n= 7,125) and the lowest rate was observed in February (7.3%, n= 5,704). While the highest figures for MNM were observed in December (11.2%, n=35), May (10.9%, n=34), January (10.3%, n=33) and the lowest was seen in October (5.1%,n=16) and August (5.8%,n=18).

Table 4.1: Distribution of reported PLTC, MNM and MD by month

Month	% of women given birth (n)	% of total PLTC (n)	% of total MNM (n)	% of total MD (n)	% of the total cases of PLTC, MNM, MD (n)
January	8.4 (6,604)	8.3 (119)	10.5 (33)	4.0 (1)	8.7 (153)
February	7.3 (5,704)	7.3 (104)	8.0 (25)	12.0 (3)	7.5 (132)
March	7.9 (6,164)	8.9 (126)	8.0 (25)	16.0(4)	8.8 (155)
April	7.9 (6,164)	9.3 (132)	7.7 (24)	16.0(4)	9.1 (160)
May	8.3 (6,529)	9.5 (135)	10.9 (34)	12.0 (3)	9.8 (172)
June	7.8 (6,103)	8.5 (121)	7.0 (22)	4.0 (1)	8.2 (144)
July	8.7 (6,799)	9.7 (138)	8.0 (25)	16.0 (4)	9.5 (167)
August	9.1 (7,121)	8.2 (117)	5.8(18)	-	7.7 (135)
September	8.5 (6,651)	8.3 (118)	8.9 (28)	-	8.3 (146)
October	9.1 (7,125)	6.3 (89)	5.1 (16)	16.0 (4)	6.2 (109)
November	8.6 (6,724)	8.5 (120)	8.9 (28)	4.0 (1)	8.5 (149)
December	8.6 (6,728)	7.0(100)	11.2 (35)	-	7.7 (135)
Total	78,446	1,419	313	25	1,757

#### 4.1.5. Reported PLTC, MNM, and MD by category of reporting hospital

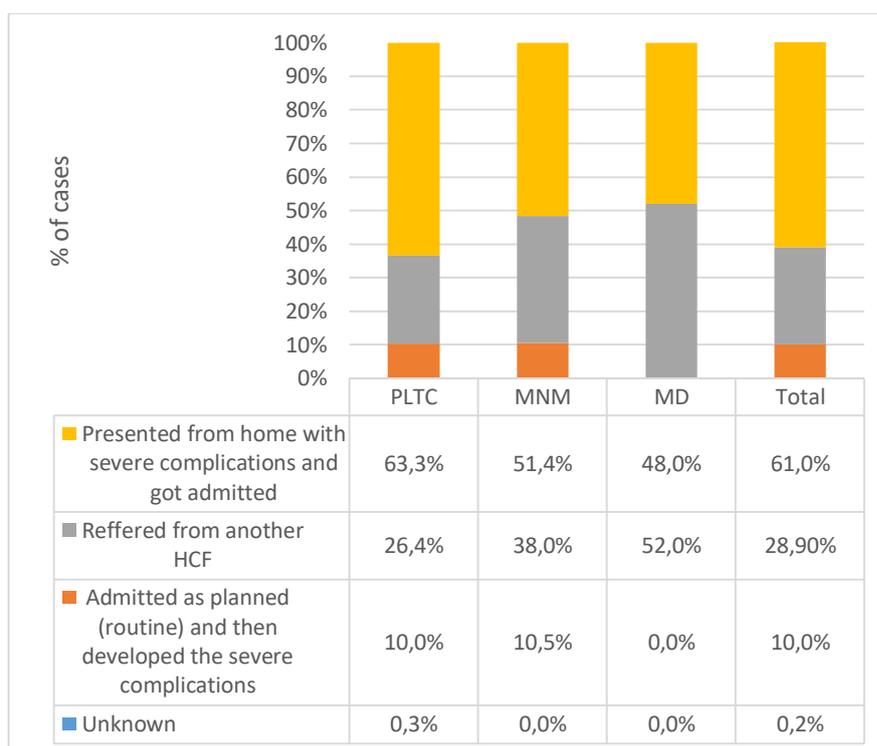
As described in chapter 3, the participating hospitals were categorised into five categories based on the type of administration (MoH administered and non-MoH administered) (**Table 4.2**). The highest number of cases reported were from MoH governorate hospitals, and the lowest were from the private hospitals. 54.2% of all deliveries in the hospitals included in the study occurred in the ten governorate hospitals (provide mostly secondary care, and some tertiary services). Most of the PLTC (59.1%, n = 839), MNM (57.2%, n = 179) and maternal deaths (48.0%, n = 12) were reported from these hospitals.

*Table 4.2: Distribution of births and reported cases of PLTC, MNM and MD by category of hospital*

Type of hospital	% of total women given birth (n)	% total live births (n)	% of total PLTC (n)	% the total MNM(n)	% the total MD (n)	(% of the total cases PLTC, MNM, MD) (n)
MoH, national level (n = 2)	19.9 (15,605)	20.0 (15,810)	19.5 (276)	23.0 (72)	32.0(8)	20.3 (356)
MoH, governorate level (n = 10)	54.2 (42,540)	54.2 (42,796)	59.1 ( 839)	57.2 (179)	48.0(12)	58.6 (1,030)
MoH, district level (n = 5)	11.6 (9,082)	11.5 (9,096)	8.0 (146)	2.2 (7)	8.0 (2)	8.8 (155)
Non-MoH, other governmental hospitals (n = 3)	9.8 (7,706)	9.8 (7,712)	9.5 (135)	16.9 (53)	12.0(3)	10.9 (191)
Non-MoH private (n = 3)	4.5 (3,513)	4.5 (3,504)	1.6 (23)	0.6 (2)	-	1.4 (25)
<b>Total (national)</b>	<b>78,446</b>	<b>78,918</b>	<b>1,419</b>	<b>313</b>	<b>25</b>	<b>1,757</b>

The two MoH-national tertiary referral hospitals cared for almost one-fifth (19.9%, n = 15,605) of the total deliveries in the country, and also recorded around one-fifth (20.3%, n = 356) of all reported cases. Under a quarter (23.0%, n = 72) of MNM and about a third (32.0%, n = 8) of maternal deaths were reported from both hospitals. About one-tenth of the cases (10.9%, n = 191) were managed in the three non-MoH hospitals providing both secondary and tertiary services. The MoH district and private hospitals (providing a mix of primary and secondary services) reported around 13.0% (n = 216) of cases, of which 11% (n = 158) were PLTC cases.

However, it was difficult to ascertain where the severe complications of these cases first occurred, because 28.9% (n = 507) of all reported cases were referred from other healthcare facilities (HCF) to the reporting hospitals, where they were identified as being PLTC, MNM, or maternal death. This figure was higher for MNM (38.0%, n = 119) and maternal deaths (52.0%, n = 13) compared to PLTC (26.4%, n = 375), as illustrated in **Figure 4.2**. These cases could have been managed in more than one healthcare facility, and the name of the health facility where the severe complications first occurred was not recorded for all cases.



*Figure 4.2: Type of admission of cases of PLTC, MNM, and MD to the reported hospital*

## 4.2. MNM indicators

Based on the figures presented above (section 4.1), the incidence of PLTC was 15.6 per 1000 ANC registered women (95% CI:10.9;20.2), and 18.1 per 1000 women giving birth (deliveries) (95% CI: 13.8;22.4). The PLTC to MNM ratio was 4.5 (95% CI: 3.3;5.8) (**Table 4.3**).

While the incidence of MNM was 3.4 (95% CI: 1.6;5.2) per 1000 ANC registered women, and 4.0 per 1000 women giving birth (deliveries) (95% CI: 2.7-5.2). The ratio of MNM was 4.0 per 1000 live births (95% CI:2.7-5.2). The severe maternal outcome ratio (SMO) was 4.3 per 1000 live births (95% CI: 3.0-5.5), while the

mortality index (MI) was 7.4% (95% CI: 4.1-10.8). The MNM to MD ratio was 10.3 (95% CI:4.0-16.0). This means that for every 10 MNM observed there was one maternal death. It should be noted that total ANC registered women was used as a proxy for the number of pregnant women, and total births were used as a proxy for total pregnancies admitted in the participating hospitals.

Table 4.3: MNM indicators

Indicator	Estimate (95% CI)
PLTC incidence per 1000 ANC registered women	15.6 (10.9;20.2) Per 1000 ANC registered women
PLTC incidence per 1000 women giving birth (deliveries)	18.1 (13.8;22.4) per 1000 deliveries
PLTC to MNM ratio	4.5 (3.3;5.8)
MNM incidence per 1000 ANC registered women	3.4 (1.6;5.2) per 1000 ANC registered women
MNM incidence per 1000 women giving birth (deliveries)	4.0 (2.7;5.2) per 1000 deliveries
MNM Ratio (MNMR) Per 1000 live births	4.0 (2.7;5.2) per 1000 live births
Severe Maternal Outcome Ratio (SMOR) (MNM + maternal deaths) per 1000 live births	4.3 (3.0;5.5) per 1000 live births
MNM to Maternal Death Ratio	10.3:1 (4.6;16.0) (n = 312:25)
Mortality Index (MD/ MD + MNM)	7.4% (4.1;10.8) (= 25/25 + 312)
Stillbirth rate (Stillbirths/live births + Stillbirths) per 1000 births	7.0 (6.0;8.0) per 1000 births

Weighted mean was used in estimating above indicators to take into account the hospitals with no MD. Thus, the weighted ratio for MNM: 1MD differed from the crude ratio (12.5:1), because 13 hospitals had no MD.

### 4.3. Characteristics of women with MNM

This section describes the characteristics of women who had MNM and compares them with women who had a PLTC.

#### 4.3.1. Sociodemographic characteristics

- *Nationality*

More than 90% (n = 281) of women who had MNM events or PLTC (1,310) were Omani nationals.

- *Marital status*

Nearly all women with MNM (99.0%, n = 309) and PLTC (99.2%, n = 1,407) were married at the time of developing PLT or MNM.

- *Age*

The maternal age was recorded for all women except for two women with PLTC. The minimum age was 15 years and the maximum was 49 years. The mean age for PLTC and MNM was 31.2 years (SD = 5.8), and 30.3 years (SD = 6.3) respectively. The highest percentages of women with both MNM and PLTC were among those aged 30-34 years with 29.8% (n = 93) and 28.8% (n = 408), respectively. The proportion of women with MNM aged 15-19 years was slightly higher than those with PTC, with 3.5% (n = 11) compared to 1.1% (n = 15). Similarly, the age group of 40 and above among the MNM group was slightly higher than those with PLTC, with 9.6% (n = 30) and 7.3% (n = 103) respectively.

A one-way ANOVA was conducted to explore the mean age difference between the PLTC and MNM, which was statistically significant:  $F(1, n = 1727) = 5.6, p = 0.018$ .

#### **4.3.2. Pregnancy history and outcome**

- *Gravidity*

The high percentage of women with MNM and PLTC were gravida 2-4, with 41.3% (n = 129) and 43.8% (n = 621) respectively. The percentage of primigravida was higher among the MNM group than the PLTC one, with 39.7% (n = 99) compared to 24.9% (n = 354). There was a slight variation observed in the percentage of grand-multigravida ( $\geq 5$ ), with 26.9% (n = 84) among mothers with MNM compared to 31.2% (n = 443) of mothers with PLTC. A one-way ANOVA was conducted and showed that the variation in gravidity between MNM and PLTC groups was statistically significant:  $F(1, n = 1728) = 4.1, p = 0.044$ .

- *Parity*

The percentage of nulliparous mothers was higher among women with MNM compared to those with PLTC, with 39.7% (n = 124) and 29.3% (n = 416) respectively. A slight variation was observed in the rest of the categories, as illustrated in **(Table 4.3)**. A one-way ANOVA test showed the variation in the parity between MNM and PLTC groups was statistically significant:  $F(1, n = 1,727) = 6.1, p = 0.014$ .

- *Previous pregnancy outcome*

Examining the history of previous pregnancy outcome of multigravida women revealed that 45.5% (n = 97) of mothers with MNM had a previous history of abortion (miscarriage) with 17.8% (n = 38) had two or more abortions. This percentage was higher than for those with PLTC (40.5%, n = 431). This difference was not

statistically significant based on the one-way ANOVA test result:  $F = (1, n = 1274) = 0.7, p = 0.394$ .

Among women with MNM who gave birth previously (175), 5.9% ( $n = 11$ ) had a history of stillbirth compare to 4.9% ( $n = 49$ ) of those with PLTC, but also this difference was not statistically significant (one-way ANOVA  $F = (1, n = 1148) = 0.0, p = 0.877$ ).

The percentage of women who gave birth previously and had caesarean section was 45.9% ( $n = 90$ ) with 9.6% ( $n = 18$ ) had three or more previous caesarean sections. This percentage was slightly higher than those with PLTC (42.4%,  $n = 425$ ) (**Table 4.4**). However, this difference was not statistically significant (one-way ANOVA:  $F = (1, n = 1161) = 1.0, p = 0.322$ ).

Table 4.4: Sociodemographic characteristics of women with PLTC or MNM

Characteristics		PLTC (n = 1,419)	MNM (n = 312)	Total (n = 1,731)	One-way ANOVA (MNM vs PLTC) (Sig. P<0.05)
<b>Nationality % (n)</b>	Omani	92.3 (1310)	90.1(281)	91.9(1,591)	
	Non-Omani	7.6 (108)	9.9 (31)	8.0 (139)	
	Unknown	0.1 (1)	-	0.1 (1)	
<b>Marital status % (n)</b>	Married	99.2 (1,407)	99.0 (309)	99.1 (1,716)	
	Divorced	0.1 (1)	-	0.1 (1)	
	Widow	-	0.3 (1)	0.1 (1)	
	Single	0.1 (1)	0.3 (1)	0.1 (2)	
	Unknown	0.7(10)	0.3 (1)	0.6 (11)	
<b>Age (years) % (n)</b>	15-19	1.1 (15)	3.5 (11)	1.5 (26)	
	20-24	13.0 (185)	17.0 (53)	13.7 (238)	
	25-29	26.2 (372)	23.7 (74)	25.8 (446)	
	30-34	28.8 (408)	29.8 (93)	28.9 (501)	
	35-39	23.5 (334)	16.3 (51)	22.2 (385)	
	≥40	7.3 (103)	9.6 (30)	7.7 (133)	
	Unknown	0.1 (1)	-	0.1 (1)	
	Mean (SD)	31.2 (5.8)	30.3 (6.3)	31.0 (5.9)	F = 5.6, p = 0.018
<b>Gravida % (n)</b>	1	24.9 (354)	31.7 (99)	26.2 (453)	
	2-4	43.8 (621)	41.3 (129)	43.3 (750)	
	≥5	443 (31.2)	26.9 (84)	30.4 (527)	
	Unknown	0.1 (1)	-	0.1 (1)	
					F = 4.1; P = 0.044
<b>Parity % (n)</b>	0	29.3 (416)	39.7 (124)	31.2 (540)	
	1	18.3 (260)	16.5 (53)	18.1 (313)	
	2-4	38.8 (550)	32.1 (100)	37.6 (650)	
	≥5	13.5 (191)	11.2 (35)	13.1 (226)	
	Unknown	0.1 (2)	-	0.1 (2)	
					F = 6.1; P = 0.014
<b>No. previous abortions in multigravida (n = 1,278) % (n)</b>	0	59.4 (632)	54.5 (116))	58.5 (748)	
	1	25.1(267)	27.7 (59)	25.5 (326)	
	≥ 2	15.4 (164)	17.8 (38)	15.8 (202)	
	Unknown	0.1 (2)	-	0.1 (2)	
				F = 0.7; P = 0.394	
<b>No. previous stillbirths in women with a previous birth (n = 1,191) % (n)</b>	0	91.3 (916)	92.6 (174)	91.5 (1,090) (91.5)	
	1	4.2 (42)	5.9 (11)	4.5 (53)	
	≥ 2	0.7 (7)	-	0.6 (7)	
	Unknown	38 (3.8)	3 (1.6)	3.4 (41)	
				F = 0.0; P = 0.877	
<b>No of previous caesarean sections in women with a previous birth (n = 1,191) % (n)</b>	0	54.9 (551)	52.1 (98)	26.5(649)	
	1	25.8 (259)	30.3 (57)	26.5 (316)	
	2	9.9 (99)	0.8 (15)	9.6 (114) (9.6)	
	≥3	6.7(67)	9.6 (18)	7.1 (85)	
	Unknown	2.7(27)	-	2.3 (27)	
				F = 1.0, P = 0.322	

We hypothesised that the relationship between the occurrence of a near-miss and a gravidity may be affected by other factors such as number of previous abortions, number of previous stillbirths, and number of previous caesarean sections. In order

to account for this, logistic regression models were fitted to assess the odds of a near-miss by the gravidity of the woman, adjusting for these factors.

The unadjusted/ crude model showed that the odds of an MNM compared to PLTC is 4.9% lower for every increase in gravidity, and this was statistically significant: crude odds ratio = 0.951 (95% CI: 0.966;0.998). Upon adjusting for number of previous abortions, number of previous stillbirths, and number of previous caesarean sections, the odds of an MNM compared to PLTC for every increase in gravidity was largely unchanged, with adjusted odds ratio = 0.936 (95% CI:0.877;0.998), suggesting that the number of previous abortions, number of previous stillbirths, and number of previous caesarean sections do not confound the relationship between near-miss and gravidity (**Table 4.5**).

*Table 4.5: Logistic regression to assess odds ratios for MNM by gravidity*

Variable name	P value	Odds Ratio	95% CI for odds Ratio	
			Upper	Lower
<b>Gravidity</b>	0.045	0.936	0.877	0.998
<b>No. previous abortions</b>	0.270	1.094	0.933	1.283
<b>No. previous stillbirths</b>	0.880	0.958	0.550	1.668
<b>No. previous C-section</b>	0.773	1.022	0.881	1.186
<b>Constant</b>	0.000	0.253		

### **4.3.3. Characteristics of the index pregnancy**

The majority (94.6%, n = 287) of the pregnancies of women with MNM were singletons, and more than 90% (n = 290) resulted from spontaneous conception. Similar percentages were observed in women with PLTC (**Table 4.6**).

Table 4.6: Characteristics of the index pregnancy

		PLTC (n = 1,419)	MNM (n = 312)	Total (n = 1,731)	Chi-square (MNM vs PLTC) <sup>1</sup>
<b>Type of pregnancy % (n)</b>	Singleton	94.4 (1342)	92.0 (287)	94.1 (1,629)	
	Multiple	3.5 (49)	4.5 (14)	3.6 (63)	
	Unknown	2.0 (28)	3.5 (11)	3.2(39)	
<b>Conception % (n)</b>	Spontaneous	93.7 (1329)	92.9 (290)	93.5 (1,619)	
	Assisted reproduction <sup>2</sup>	3.2 (45)	3.8 (12)	3.3 (57)	
	Unknown	3.2 (45)	3.2 (10)	3.2 (55)	
<b>Booking for ANC % (n)</b>	Booked	90.8 (1,288)	91.0 (284)	90.8 (1,572)	
	Un-booked	8.7 (124)	8.7 (27)	8.7 (151)	
	Unknown	0.5 (7)	0.3 (1)	0.5 (8)	
<b>The timing of booking (trimester-weeks of gestational age) % (n)</b>	First (≤12 wk.)	33.9 (436)	39.8 (113)	34.9 (549)	
	Second (13-26 wk.)	23.1 (297)	26.1 (74)	23.6 (371)	
	Third (≥27 wk.)	2.6 (33)	2.5 (7)	2.5 (40)	
	Unknown	40.5 (522)	31.7 (90)	38.9(612)	
					X <sup>2</sup> = 0.2 P = 0.884
<b>Previous pregnancy complications during the index pregnancy % (n)</b>	Yes	44.7 (634)	49.7 (155)	45.6 (789)	
	No	54.1 (768)	49.4 (154)	53.3 (922)	
	Unknown	17(1.2)	3(1.0)	20 (1.2)	
					X <sup>2</sup> = 2.5; p = 0.115
<b>Previous admission during index pregnancy % (n)</b>	Yes	20.3 (288)	23.1 (72)	20.8 (360)	
	No	75.8 (1075)	73.4 (229)	75.3 (1308)	
	Unknown	3.9(56)	3.5 (11)	3.9 (67)	
					X <sup>2</sup> = 1.1; p = 0.287

<sup>1</sup> Significance level  $p < 0.05$

<sup>2</sup> Includes all types of medical procedures to treat infertility

#### 4.3.3.1. Antenatal care (ANC) booking status and attendance

Out of 312 women with MNM, 91.0% (n = 284) were registered (booked) for ANC care. Only 8.7% (n = 27) of women were not registered, and information regarding booking status was not available for one woman. Similarly, the majority (90.8%, n = 1,288) of women with PLTC were registered for ANC, with only 8.7% (n = 124) not being registered. For those who were registered for ANC care, information was not available for 31.7% (n = 90) of the MNM group and 40.5% (n = 522) of the PLTC group. Of the booked mothers with MNM, 39.8% (n = 113) were registered during the first trimester. This percentage was slightly higher than for those with PLTC (33.9%, n = 436). The chi-square test showed there was no significant difference in the timing of ANC registration status between women with MNM and PLTC =  $X^2$  (2, n = 960) = 0.2,  $p = 0.884$ ).

**Figure 4.3** summarises the ANC attendance by MNM and PLTC for ANC registered mothers (1,572). Less than 5% (n = 6) of mothers with MNM had one ANC visit,

26.4% (n = 75) had two to six visits, and 30.1% (n = 94) had visited the ANC care clinic seven times or more. There was insufficient information to determine the frequency of ANC for 38.4% (n = 109) of women who registered for ANC. There was no difference in the median number of ANC visits for MNM (7.0; SD = 3.9) and PLTC (7.0; SD = 3.5). Also based on the results of the Mann-Whitney U test there was no statistically significant difference between the two groups regarding ANC attendance: (U=57830.5,  $p = 0.526$ ). However, it should be noted that the percentage of mothers with insufficient information on the number of ANC visits was high among PLTC (47.0%, n = 606 among PLTC vs 38.4%, n = 109 among MNM).

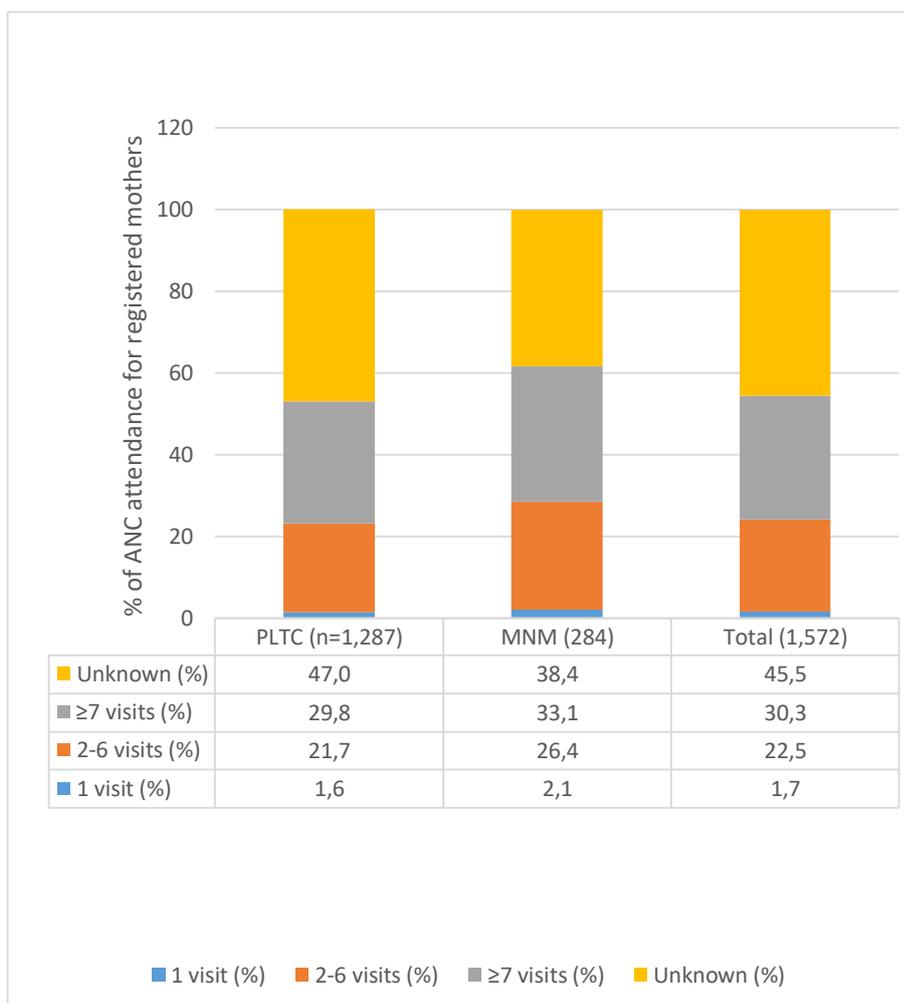


Figure 4.3: ANC attendance of registered mothers with MNM or PLTC

#### 4.3.3.2. Previous pregnancy complications

About half (49.7%, n = 155) of mothers with MNM were diagnosed with at least one complication during the index pregnancy before the reported episode of near-miss (**Table 4.5**). This percentage was slightly higher than for those with PLTC (44.7%,

n = 634). However, this difference was not statistically significant (chi-square test =  $X^2$  (1, n = 1,711) = 2.5,  $p = 0.115$ )

#### 4.3.3.3. Previous admission during the index pregnancy

Examining the history of previous admissions of mothers with MNM during index pregnancy revealed that 73.4% (n = 229) were not admitted compared to 75.8% (n = 1075) with PLTC. A chi-square test showed this difference was not statistically significant:  $X^2$  (1, n = 1,664) = 1.1,  $p = 0.287$ .

#### 4.3.3.4. Pre-existing medical disorder

Over one-third (34.9%, n = 109) of women with MNM were suffering from pre-existing medical disorders. This proportion was higher than for those with PLTC (25.7%, n = 365). The chi-square test for independence showed the difference was statistically significant =  $X^2$  (1, n = 1,705) = 10.8,  $p = 0.001$ ,  $phi = 0.08$ . Using logistic regression, the odds ratio of woman having MNM compare to PLTC if she has pre-existing medical disorder is 1.5 higher. This was statistically significant: OR = 1.5 (95% CI = 1.19;2.01) **Table 4.7.**

Table 4.7: Results of logistic regression of pre-existing medical disorders in MNM

		df	Sig.	Exp(B)	95% C.I. for EXP(B)	
					Lower	Upper
Step 1 <sup>a</sup>	Pre-existing medical disorder	1	.001	1.549	1.191	2.013
	Constant	1	.000	.193		

## 4.4. Chapter summary

Between October 2016 and September 2017, a total of 90,968 women registered in ANC clinics in Oman. During the same period, 78,446 women gave birth in the 23 participating hospitals. Of the women admitted during pregnancy, childbirth, and the postpartum period during the same period in these hospitals, a total of 1,731 women were identified with potentially life-threatening conditions. Out of these, 312 women fulfilled the criteria of MNM. One woman with MNM had 2 MNM events, therefore the total of MNM events was 313.

The incidence of MNM was 3.4 per 1000 ANC registered women (95% CI 1.6;5.2), and 4.0 per 1000 women giving birth (95% CI 2.7;5.2). The MNM ratio was 4.0 per 1000 (95% CI 2.7;5.2) live births, and the SMO ratio was 4.3 per 1000 (95% CI

3.0;5.5) live births. The ratio of MNM to MD was 10.3:1 (95% CI 4.6;16.0) and the MI was 7.4% (95% CI 6.0;8.0).

Compared with PLTC, the percentage of women with MNM aged 15-19 years was slightly higher than those with PTC with 3.5% (n = 11) compare to 1.1% (n = 15). Also, the percentage of those aged 40 and above was slightly higher than those with PLTC with 9.6% (n = 30) and 7.3% (n = 103) respectively. There was a significant statistical difference between the mean age of MNM and PLTC, based on one-way ANOVA test ( $F = (1, n = 1727) = 5.6, p = 0.018$ ).

A slight variation was observed in the gravidity between MNM and PLTC. The percentage of primigravida was higher among MNM group than PLTC, with 39.7% (n = 99) compare to 24.9% (n = 354). The variation was statistically significant (one-way ANOVA test  $F = (1, n = 1,728) = 4.1, p = 0.044$ ). Similarly, there was a variation observed in parity between the two groups, with a higher percentage of nulliparous women within MNM group (39.7%, n = 124) than those with PLTC (29.3%, n = 416). This variation was also statistically significant (one-way ANOVA test  $F = (1, n = 1,727) = 6.1, p = 0.014$ ). After adjusting for other previous pregnancy characteristics (number of previous abortions, number of previous stillbirths, and number of previous caesarean sections), the odds ratio of a near-miss compared to PLTC is 6.4% lower for every increase in gravidity, and was statistically significant: adjusted odds ratio = 0.936 (95% CI 0.877-0.998). Pre-existing medical disorders was higher among women with MNM than those with PLTC, with 34.9% (n = 109) versus 25.7% (n = 365). The odds ratio of woman having MNM compared to PLTC if they have a pre-existing medical disorder is 1.5 times higher: odds ratio = 1.5 (95% CI = 1.9;2.0).

No significant statistical difference was observed between mothers with MNM and those with PLTC regarding previous pregnancy outcome, history of previous complications, and previous admission during the index pregnancy.

## 5. Underlying Causes of MNM, Identification Criteria, and Description of Events

This chapter is the first chapter that focuses on answering the third research question: what are the underlying causes of MNM?

As described in the methodology chapter, the WHO application of ICD-10 to classify deaths during pregnancy, childbirth and the puerperium (ICD-MM) (WHO, 2012) was used to classify the underlying causes of MNM, and, to develop identification criteria for MNM. The chapter presents the reported underlying causes by health care providers by ICD-MM groups and the specific causes within each group. It also compares these causes with those of PLTC and maternal deaths. Section two of the chapter presents the identification criteria for MNM for each group of causes. While section three describes timing of occurrence of the MNM events and the category of the reported hospitals by each cause. Section four reports on the interventions the mothers with MNM received during their hospitalisation by cause, whereas mode of delivery and pregnancy outcome are described in section five.

### 5.1. Reported underlying causes of MNM

#### 5.1.1. Underlying cause of MNM assigned by health providers

Examining the reported underlying causes of MNM as assigned by health providers reveals that the most frequent causes were in the group of hypertensive disorders of pregnancy, accounting for 44.1% (n = 138) of all MNM events, followed by obstetric haemorrhage (22.7%, n = 71) and non-obstetric complications (17.9%, n = 56). Pregnancy with abortive outcome was assigned as a cause of 5.8% (n = 18) of MNM events, while the group of other-obstetric complications was considered responsible for 5.1% (n = 16). Groups accounting for less than 5% included pregnancy-related infections (1.9%, n = 6), unanticipated complications of management (1.9%, n = 6), and other severe complications (0.6%, n = 2) (**Figure 5.1**).

As mentioned in chapter 4, there were 312 women with MNM and 313 MNM events. One woman had two MNM events: one due to obstetric haemorrhage and the second due to a pregnancy-related infection.

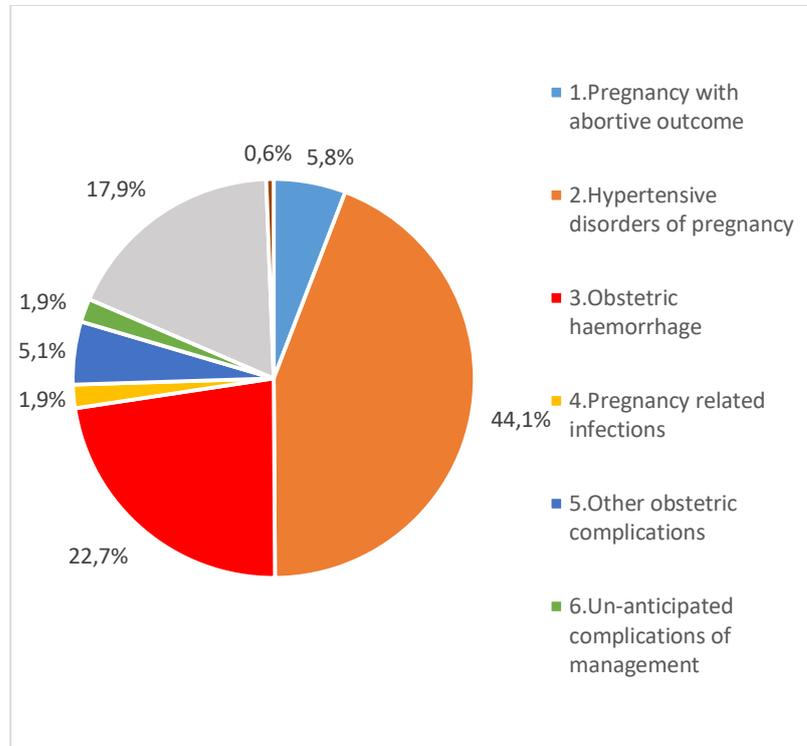


Figure 5.1: Underlying causes of MNM by ICD-MM groups (n = 313 events)

### 5.1.2. Specific causes of MNM by ICD-MM group

The following sub-sections present the specific causes of MNM by ICD-MM group. It should be noted that more than one cause or complication within a group could be assigned to a single case.

#### 5.1.2.1. Group 1: Pregnancy with abortive outcome

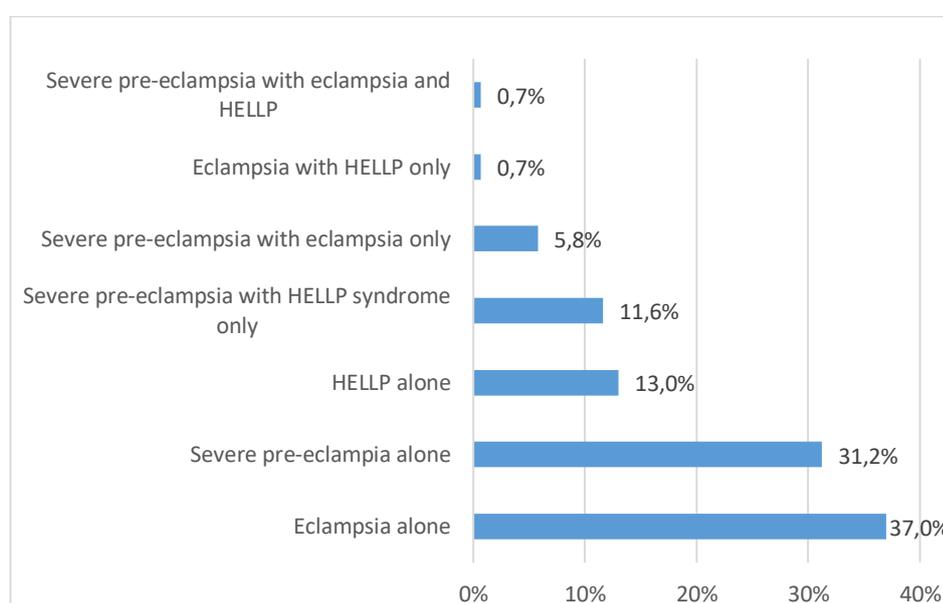
Relatively few MNM cases were reported under this group (5.8%, n = 18). They were distributed between miscarriage (50.0%, n = 9), ruptured ectopic pregnancy (38.9%, n = 7), and induced abortion (11.1%, n = 2), with no case of molar pregnancy. Severe haemorrhage was the most common complication (77.8%, n = 114), followed by sepsis (27.8%, n = 5). There was no case related to abortion reported with thyroid crisis or pulmonary embolism.

#### 5.1.2.2. Group 2: Hypertensive disorders of pregnancy

The group of hypertensive disorders of pregnancy was the leading group for underlying causes for MNM (44.1%, n = 138). Pregnancy-induced hypertension (PIH)

was more frequent than pre-existing hypertension, with 89.1% (n = 123) compared to 10.1% (n = 14). The type of hypertension was not specified in one case (0.7%).

Severe preeclampsia was the most common cause and was reported in nearly half of all MNM events with hypertensive disorders (49.1%, n = 68). Eclampsia was recorded in 61 (44.2%), giving an incidence of eclampsia of 0.8 per 1,000 women giving birth. HELLP syndrome was attributed to 36 (26.1%) cases. Severe pre-eclampsia with HELLP syndrome were recorded in 11.6% (n = 16) of the events, and 5.8% (n = 8) were attributed to severe pre-eclampsia with eclampsia. One woman had eclampsia with HELLP syndrome (0.7%), and a single case had all three disorders (**Figure 5.2**).



*Figure 5.2: Specific causes of hypertensive disorders of pregnancy in MNM*

### 5.1.2.3. Group 3: Obstetric haemorrhage

Obstetric haemorrhage was the second most common attributed cause of MNM (22.7%, n = 71). Placentation disorders (placental previa, accrete, incerta, and percreta) were the main cause of severe obstetric haemorrhage (39.4%, n = 28), followed by uterine atony (28.2%, n = 20) and placenta abruption (12.7%, n = 9) (**Figure 5.3**).

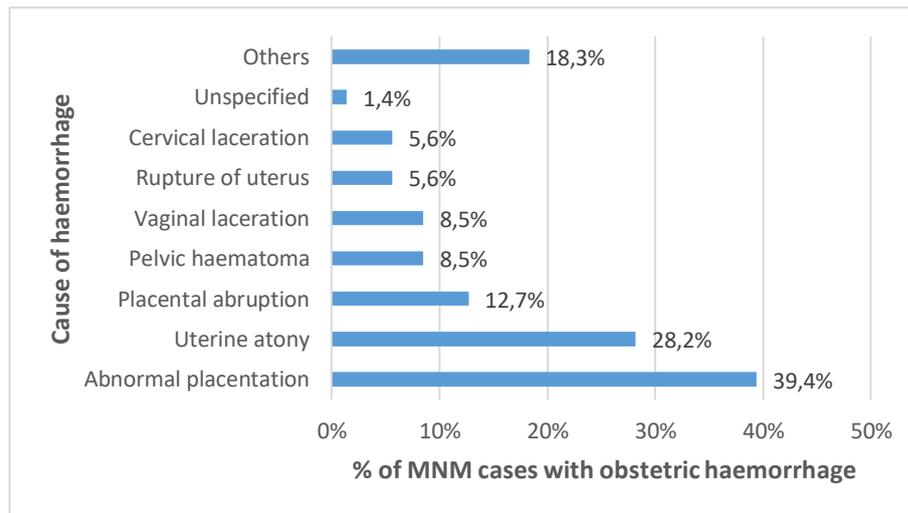


Figure 5.3: Specific causes of obstetric haemorrhage in MNM

54.9% (n = 39) of cases with haemorrhage had previous caesarean section, and 19.7% (n = 14) had three or more respectively for those with obstetric haemorrhage. Examining the cases with abnormal placentation reveals that more than half (53.6%, n = 15) had two or more caesarean sections, with more than one-third (35.7%, n = 10) having had three caesarean sections (**Table 5.1**).

Table 5.1: Number of caesarean sections in MNM with obstetric haemorrhage and abnormal placentation

No. previous caesarean section	No. MNM cases with obstetric haemorrhage	%
0	7	25.0
1	6	21.4
2	2	7.1
3	10	35.7
4	3	10.7
<b>Total</b>	<b>28</b>	<b>100.0</b>

#### 5.1.2.4. Group 4: Pregnancy-related infections

This group was assigned to only 1.9% (n = 6) of MNM events. Within the group, the leading cause was puerperal sepsis (83.3%, n = 5), followed by severe genitourinary tract infection (16.7%, n = 1). No MNM case was reported with chorioamnionitis.

#### 5.1.2.5. Group 5: Other obstetric complications

Relatively few MNM cases were reported in this group (5.1%, n = 16). Peripartum cardiomyopathy was the leading cause, accounting for 37.5% (n = 6) of all MNM assigned to group 5. Obstetric embolism (massive pulmonary embolism (PE) and amniotic fluid embolism (AFE)) accounted for 31.3% (n = 5) of cases. The remaining cases had obstetric trauma (25.0%, n = 4) and Wernicke's encephalopathy (6.3%, n

= 1). No MNM events were recorded due to intentional self-harm or venous complications.

#### 5.1.2.6. Group 6: Unanticipated complication of management

Only a few MNM events were reported as a result of unanticipated complications of management (1.9%, n = 6). Of these six events, 83.3% (n = 5) were due to complications of anaesthesia (succinylcholine apnoea and cerebral anoxia), and the remaining 16.7% (n = 1) were due to unmatched blood transfusion.

#### 5.1.2.7. Group 7: Non-obstetric complications

Non-obstetric complications were the third most common cause of MNM, contributing to 17.9% (n = 56) of all MNM events. Haematological disorders, mainly sickle cell disease (SCD), comprised the leading cause within this group, attributed to more than half of cases (55%, n = 31). Pre-existing cardiac disorders (cardiomyopathy, atrial fibrillation, and severe valvular heart disease) were the second most common causes (29.0%, n = 9), followed by respiratory disorders (10.7%, n = 6). Infection, endocrine disorders, and genitourinary tract disorders contributed to less than 10%. No MNM event was related to connective tissue disorders, disorders of the gastrointestinal tract (GIT), or neoplasm (**Figure 5.4**).

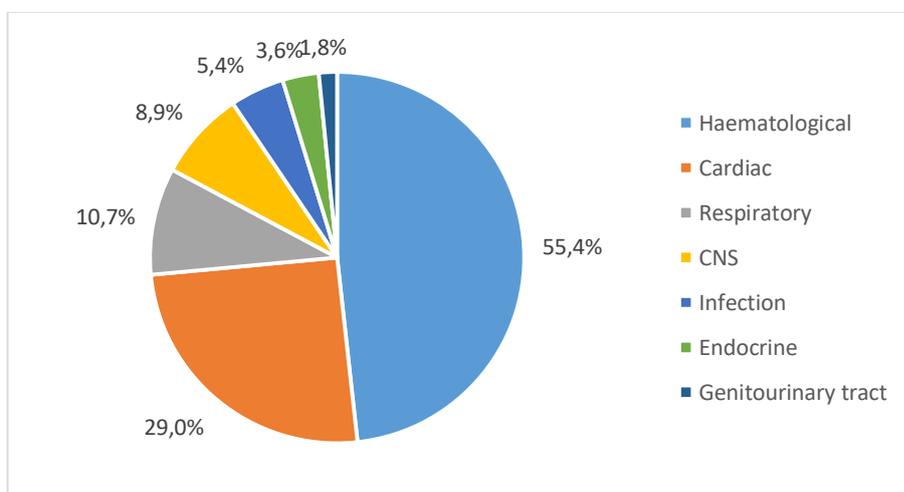


Figure 5.4: Specific causes of non-obstetric complications in MNM

#### 5.1.2.8. Group 8: Other severe complications

Five cases were reported in this group. After examining these cases, three were re-classified under the previous seven groups: unmatched blood transfusion, bladder injury, and Wernicke's encephalopathy (**Annex 11**). The remaining two cases were reported with ovarian plexus bleeding with haemoperitoneum, and the second case had a cardiac arrest with an unknown cause during LSCS.

### 5.1.3. Specific causes from overall MNM events

For the 313 MNM events, severe pre-eclampsia was the most common reported cause and identified in 21.7% (n = 68) of all MNM events, followed by eclampsia with 19.5% (n = 61) and HELLP syndrome with, 11.5% (n = 36). SCD crisis was attributed to 9.6% (n = 30), abnormal placentation to 8.9% (n = 28), and uterine atony was assigned to 6.4% (n = 20) of the MNM events. The rest of the causes contributed to less than 5% of the MNM events (**Table 5.2**).

Table 5.2: Summary of specific causes of MNM events (n = 313)

Group/ specific cause	No. times identified	% within the group	% of total MNM events (313)
Pregnancy with abortive outcome	18	-	5.8
Severe haemorrhage	14	77.8	4.5
Sepsis	5	27.8	1.6
Hypertensive disorders of pregnancy	138	-	44.1
Severe pre-eclampsia	68	49.1	21.7
Eclampsia	61	44.2	19.5
HELLP	36	26.1	11.5
Obstetric haemorrhage	71	-	22.7
Abnormal placentation	28	39.4	8.9
Uterine atony	20	28.2	6.4
Placental abruption	9	12.7	2.9
Pelvic haematoma	6	8.5	1.9
Vaginal laceration	6	8.5	1.9
Rupture uterus	5	5.6	1.6
Cervical laceration	4	5.6	1.3
Unspecified	1	1.4	0.3
Others	13	18.3	4.2
Pregnancy-related infections	6	-	1.9
Puerperal sepsis	5	83.3	1.6
Infection of GUT	1	16.7	0.3
Other obstetric complications	16	-	5.1
Peripartum cardiomyopathy	6	37.5	1.9
Obstetric embolism	5	31.3	1.6
1. Massive PE	4	25.0	1.3
2. AFE	1	6.25	0.3
Obstetric trauma to other pelvic organs	4	25.0	1.3
Wernicke's encephalopathy	1	6.3	0.3
Unanticipated complications of management	6	-	1.9
Complication of anaesthesia	5	83.3	1.6
1. Suxamethonium (succinylcholine) apnoea	4	66.7	1.3
2. Cerebral anoxia	1	16.7	0.3
Transfusion of unmatched blood	1	16.7	0.3

Group/ specific cause	No. times identified	% within the group	% of total MNM events (313)
Non-obstetric complications	56	-	17.9
Haematological	31	55.0	9.9
1. SCD crisis	30	53.6	9.6
2. Thrombotic thrombocytopenic purpura	1	1.8	0.3
Cardiac	9	29.0	2.9
1. Cardiomyopathy	7	12.5	2.2
2. Acute atrial fibrillation	1	1.8	0.3
3. Severe valvular heart disease	1	1.8	0.3
Respiratory	6	10.7	1.9
1. Pulmonary oedema	3	5.4	1.0
2. Acute respiratory distress syndrome	2	3.6	0.6
3. Severe asthma	1	1.8	0.3
Central nervous system	5	8.9	1.6
1. Epilepsy	3	5.4	1.0
2. Intracranial and subarachnoid haemorrhage	2	3.6	0.6
Infection	3	5.4	1.0
1. Severe pneumonia	2	3.6	0.6
2. Sepsis	1	1.8	0.3
Endocrine (diabetes ketoacidosis-DKA)	2	3.6	0.6
Genitourinary tract (acute renal failure)	1	1.8	0.3
Other severe complications	2	-	0.6
Ovarian plexus bleeding	1	50.0	0.3
Cardiac arrest with unknown cause	1	50.0	0.3

#### 5.1.4. Comparing causes of MNM with causes of PLTC and maternal deaths

Comparing the causes of MNM with those of PLTC and maternal deaths reveals that the first three leading causes of MNM (hypertensive disorders of pregnancy, obstetric haemorrhage, and non-obstetric complications) were also the main causes for PLTC and maternal deaths. The leading cause for PLTC was obstetric haemorrhage (51%, n = 723), followed by hypertensive disorders of pregnancy (27.7%, n = 393) and pregnancy with abortive outcome (7.1%, n = 101). Most maternal deaths were due to non-obstetric complications (48.0%, n = 12) followed by other obstetric complications (16.0%, n = 4), hypertensive disorders (12.0%, n = 3) and obstetric haemorrhage (12.0%, n = 3) (**Figure 5.5**). **Annex 12** presents and compares the specific causes of MNM, PLTC, and maternal deaths.

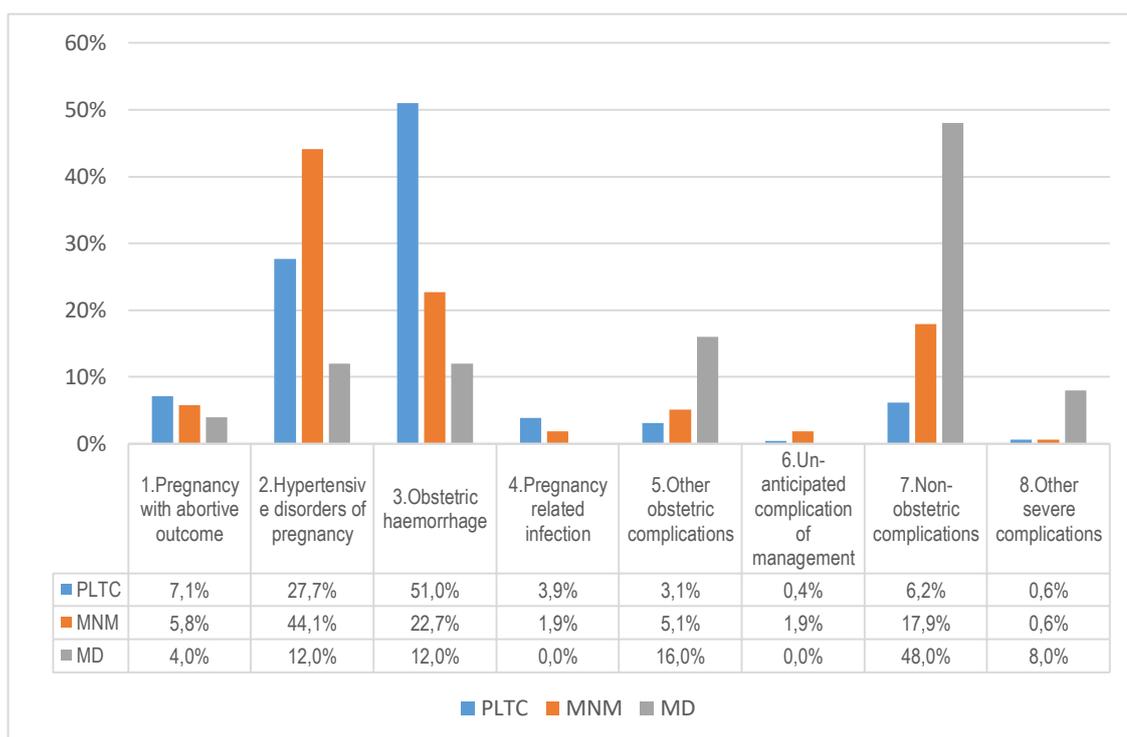


Figure 5.5: Underlying cause for PLTC, MNM and MD by ICD-MM group

Obstetric haemorrhage had the highest PLTC to MNM ratio; with every 10 PLTC observed there was one MNM. Unanticipated complications of management group had the lowest ratio with 0.8:1, followed by non-obstetric complications (1.6:1). Hypertensive disorders of pregnancy had a better outcome, with one death observed for every 46 MNM, while the lowest outcome was for the group of other obstetric complications, with a ratio of MNM: 1MD of 4.0:1 (Table 5.3).

Table 5.3: Ratio of PLTC to MNM and MNM to MD by ICD-MM group

	PLTC: MNM	MNM:MD
Pregnancy with abortive outcome	5.6:1 (101:18)	18.0:1 (18:1)
Hypertensive disorders of pregnancy	2.8:1 (393:138)	46.0:1 (138:3)
Obstetric haemorrhage	10.2:1 (723:71)	23.7:1 (71:3)
Pregnancy-related infections	9.3:1 (56:6)	-
Other obstetric complications	2.8:1 (44:16)	4.0:1 (16:4)
Unanticipated complications of management	0.8:1 (5:6)	-
Non-obstetric complications	1.6:1 (88:56)	4.7:1 (56:12)
Other severe complications	4.5:1 (9:2)	1.0:1 (2:2)
Total	4.5:1 (1,419:313)	10:1 (313:25)

## 5.2. Criteria used to identify MNM

This section describes the frequency of reported criteria used to identify the 313 MNM events and the percentage of MNM in which these criteria were recorded as per the ICD-MM group. It should be noted a woman can have one or more criteria to be classified as MNM. No MNM cases were reported with the following causes: thyroid crisis, acute fatty liver, suicidal attempts, thyroid crisis, gastrointestinal conditions, and connective tissue disorders, thus their corresponding criteria are not presented.

### 5.2.1. Group 1: Pregnancy with abortive outcome

- *Severe haemorrhage*

The 14 events with severe haemorrhage were identified by three out of the four proposed criteria: shock, massive blood transfusion, and hysterectomy. Shock was the most common reported criterion with 57.1% (n = 8) events, followed by massive blood transfusion (28.6%, n = 4) and hysterectomy (21.4%, n = 3). Coagulopathy was not used as a criterion for MNM in these 14 events.

- *Sepsis*

All the three proposed criteria for sepsis were identified in the five reported events. Admission to ICU/HDU was the most frequently recorded criteria where it was satisfied by 80.0% (n = 4) events, followed by severe sepsis (60.0%, n = 3) and septic shock (20.0%, n = 1).

### **5.2.2. Group 2: Hypertensive disorders of pregnancy**

All the proposed criteria for hypertensive disorders were used for identifying the 138 MNM events in this group. From the 138 reported events, eclampsia was the most frequent recorded criteria with 44.2% (n = 61) followed by impaired liver function (22.5%, n = 31) and thrombocytopenia (15.9%, n = 22). Pulmonary oedema, impaired renal function, and jaundice were observed in 11.6% (n = 16), 5.1% (n = 7), and 1.4% (n = 2) of events, respectively. For HELLP syndrome (36), elevated liver enzymes was the most common observed marker (83.7%, n = 31) followed by low platelet count (73.0%, n = 27) and haemolysis (40.5%, n = 15).

### **5.2.3. Group 3: Obstetric haemorrhage**

All four proposed criteria for this group were used to identify the 71 MNM events with severe haemorrhage. Massive blood transfusion was the most frequent criterion, with 63.4% (n = 45) of the events. Hysterectomy and shock had the same frequency with 35.2% (n = 25) each, while coagulopathy was recorded in 12.7% (n = 9) of events.

### **5.2.4. Group 4: Pregnancy-related infection**

Similar to sepsis related to abortion, all three criteria were used in the six reported events for this group. Admission to ICU/HDU was the most common criterion and was recorded in all events. Severe sepsis and septic shock were reported for 66.7% (n = 4) and 16.7% (n = 1) of events, respectively.

### **5.2.5. Group 5: Other obstetric complication**

- *Obstetric embolism*

Four criteria were proposed for AFE: acute hypotension, seizure, coagulopathy, and cardiac arrest. Of these, acute hypotension was recorded in the single reported event. For massive PE, four MNM events were reported using three out of the eight criteria. They were findings of right ventricular (RV) dysfunction in echocardiogram (75%, n = 3), findings of massive PE in computed tomographic pulmonary angiography (CTPA) (50%, n = 2), and positive signs and laboratory test of myocardial injury (25%, n = 1). The remaining five criteria, which were not used, were severe hypotension, shock, cardiac arrest, collapse, and hypoxaemia.

- *Obstetric trauma*

Different criteria were observed in the four events with obstetric trauma: acute hypotension, hypovolemic shock, blood transfusion, and presence of organ failure.

Each event satisfied one criterion. The unreported criterion under this cause was neurogenic shock.

- *Cardiomyopathy*

Four out of the seven proposed criteria were utilised in reporting the six events with cardiomyopathy: pulmonary oedema, shock, cardiac arrest, and the criterion of intubation and ventilation were not related to anaesthesia. Pulmonary oedema and shock were recorded in 83.3% (n = 5) and 33.3% (n = 2) of events, respectively. Cardiac arrest criterion and intubation and ventilation not related to anaesthesia were reported by one event each (16.7%). The unreported criteria were severe hypoperfusion, use of continuous vasoactive drug, and cardiopulmonary resuscitation (CPR).

- *Wernicke's encephalopathy*

The single MNM event with Wernicke's encephalopathy was reported, with permanent neurological damage.

### **5.2.6. Group 6: Unanticipated complication of management**

Four criteria were proposed for complication of anaesthesia: admission to ICU due anaesthesia complication, collapse after anaesthesia, persistent severe headache, and cardiac arrest. All five events under this group satisfied the criterion of admission to ICU due anaesthesia complication. The event of unmatched blood transfusion was identified using two criteria: coagulopathy and intubation and ventilation not related to anaesthesia.

### **5.2.7. Group 7: Non-obstetric complications**

- *Infection*

All the three MNM events related to sepsis were recorded under the criterion of admission to ICU/HDU (100.0%). One event was reported using septic shock criterion (33.3%).

- *Cardiac (including pre-existing hypertension) conditions*

The ten events with pre-existing cardiac conditions were reported using four out of the eight proposed criteria: pulmonary oedema, intubation and ventilation not related to anaesthesia, shock and continuous use of vasoactive drug. Pulmonary oedema was the most frequent criterion where it was fulfilled by 70.0% (n = 7) of the events followed by intubation and ventilation not related to anaesthesia (30.0%, n = 3). Shock and continuous use of vasoactive drug had the same frequency with 20.0%

(n = 2). The unreported criteria were cardiac arrest, stroke, CPR and severe hypoperfusion.

- *Respiratory conditions*

For respiratory conditions, three out of the five proposed criteria were observed in the six reported events: low oxygen saturation, abnormal respiratory rate, and intubation and ventilation not related to anaesthesia. In half of the events (n = 3) women had low oxygen saturation, and in one-third (n = 2) they had abnormal respiratory rate. Also, one-third (n = 2) were intubated and ventilated. The remaining unreported criteria were acute cyanosis and gasping.

- *Haematological conditions*

For SCD, five out of the six proposed criteria were observed in the 30 reported events: admission to ICU/HDU, presence of acute chest syndrome (ACS), hyperhaemolysis with severe anaemia, PE, and infection with sepsis. Admission to ICU/HDU and presence of ACS were the most frequently identified criteria, with 70.0% (n = 21) and 63.3% (n = 19) respectively. Severe anaemia and PE were reported in 26.7% (n = 8) and 6.7% (n = 2) of events, respectively. Infection with sepsis was the least reported criterion, with 3.3% (n = 1) of events. The unidentified criterion was evidence of multiorgan failure.

A single event related to idiopathic thrombocytopenia was identified by two out of the four proposed criteria: severe renal involvement, and admission to HDU/ICU. The remaining two unreported criteria were neurological involvement and cardiac involvement.

- *Genitourinary conditions*

Under this category, three criteria were proposed for ARF: high creatinine level, renal dialysis, and oliguria not responsive to fluid or diuretics. The single event related to ARF was reported with high creatinine level.

- *Endocrine conditions*

Two events with diabetes ketoacidosis were recorded under this category, in both of which the women fulfilled the criteria of disorientation/ coma. In one of them the woman had severe acidaemia. Acute respiratory distress syndrome and hypokalaemia were the remaining unreported criteria.

- *Central nervous system conditions*

Of the four proposed criteria, two were used to report the five events with central nervous system conditions: uncontrolled fits/ status epilepticus, and stroke. Uncontrolled fits/status epilepticus was observed in three out of the five events, while stroke was observed in two. The unreported criteria were prolonged unconsciousness/coma and total paralysis.

- *Group 8: Other severe complications*

The MNM event related to ovarian plexus bleeding was reported with shock. The second event under this group was reported with cardiac arrest, shock and received CPR.

**Table 5.4** summarises the identification criteria used to identify MNM events for the reported causes and classifies these criteria into three categories: clinical, management, and laboratory. The frequency use of clinical criteria was higher than for management and laboratory criteria. Clinical criteria were used to classify MNM except for those with massive PE, ARF, complications of anaesthesia, and life-threatening reaction due to unmatched blood transfusion. It should be noted that, except for complications of anaesthesia, only one case was reported with these causes.

Table 5.4: Frequency of reported identification criteria for MNM events

Specific cause (no. reported events)	No. proposed criteria for the cause	No. (%) of used criteria	The criterion	No. (%) of times identified in the reported events based on the category		
				Clinical	Management	Laboratory
<b>Severe haemorrhage (n = 42) <sup>1</sup></b>	4	4 (100.0)	Shock	33		
			Blood transfusion		48	
			Hysterectomy for haemorrhage		28	
			Coagulopathy			9
<b>Sepsis (n = 14) <sup>2</sup></b>	4	4 (100.0)	Admission to HDU/ICU		13	
			Severe sepsis			7
			Septic shock	3		
<b>Massive PE (n = 4)</b>	8	3 (37.5)	CTPA			1
			Echo finding of RV dysfunction			3
			Myocardial injury			1
<b>AFE (n = 1)</b>	4	1 (25.0)	Acute hypotension	1		
<b>Hypertensive disorders of pregnancy (n = 138)</b>	6	6 (100.0)	Eclampsia	61		
			Impaired liver function			31
			Thrombocytopenia			22
			Pulmonary oedema	16		
			Impaired renal function			7
			Jaundice	2		
<b>HELLP syndrome (36)</b>	3	3 (100.0)	Haemolysis			15
			Elevated liver enzyme			31
			Low platelet count			27
<b>Obstetric trauma (n = 4)</b>	4	3 (75.5)	Acute hypotension	1		
			Hypovolemic shock			

<sup>1</sup> Includes events of haemorrhage from the groups “pregnancy with abortive outcome” and “obstetric haemorrhage”.

<sup>2</sup> Includes events with sepsis from the groups “pregnancy with abortive outcome”, “pregnancy-related infection”, and “non-obstetric complications”.

Specific cause (no. reported events)	No. proposed criteria for the cause	No. (%) of used criteria	The criterion	No. (%) of times identified in the reported events based on the category		
				Clinical	Management	Laboratory
			Blood transfusion		1	
			Organ failure (bladder injury) <sup>3</sup>	1		
<b>Wernicke's encephalopathy (n = 1)</b>			Permanent neurological damage <sup>4</sup>	1		
<b>Cardiac conditions (n = 16) (Including t cases with peripartum cardiomyopathy)</b>	8	5 (62.5)	Pulmonary oedema	12		
			Intubation and ventilation not related to anaesthesia		3	
			Shock	4		
			Continuous use of vasoactive drug			2
			Cardiac arrest	1		
<b>Respiratory conditions (n = 6)</b>	5	3 (60.0)	Low oxygen saturation	3		
			Abnormal respiratory rate	2		
			Intubation and ventilation not related to anaesthesia		2	
<b>GUT-Acute renal failure (n = 1)</b>	3	1(33.3)	High creatinine level			1
<b>SCD (n = 30)</b>	6	5 (83.3)	Admission to HDU/ICU		21	
			Acute chest syndrome	19		
			Hyperhaemolysis and severe anaemia			8
			Pulmonary embolism			2
			Infection and evidence of sepsis			1
<b>Thrombotic thrombocytopenic purpura (n = 1)</b>	4	1 (25.0)	Severe renal impairment			1
			Admission to HDU/ICU		1	

<sup>3</sup> The case was reported with the criteria of organ failure listed under the group of "other severe complication".

<sup>4</sup> The case was reported with the criteria of organ failure listed under the group of "other severe complication".

Specific cause (no. reported events)	No. proposed criteria for the cause	No. (%) of used criteria	The criterion	No. (%) of times identified in the reported events based on the category		
				Clinical	Management	Laboratory
Diabetes ketoacidosis (n = 2)	4	2 (50.0)	Disorientation/ coma	2		
			Severe acidaemia			1
Central nervous system (n = 5)	4	3 (75.0)	Uncontrolled fits/Status epilepticus	3		
			Stroke	2		
Complication of anaesthesia (n = 5)	4	1 (25.0)	Admission to ICU		1	
			Intubation and ventilation not related to anaesthesia		1	
Unmatched blood transfusion (n = 1)			Coagulopathy			1
Other severe complications (n = 2)			Shock	2		
			Cardiac arrest	1		
			CPR			1
<b>Total</b>				180	120	172

### 5.3. Distribution of causes of MNM by timing of MNM event and category of reporting hospital

#### 5.3.1. Pregnancy stage at the time of occurrence of MNM event

The highest proportion of MNM events occurred during the antenatal period (52.1%, n = 163) followed by the postpartum period (28.4%, n = 89). In total 19.5% (n = 61) were considered to be intrapartum MNM events (from the onset of labour to end of third stage). The majority (74.2%, n = 127) of antenatal events occurred during the third trimester ( $\geq 27$  weeks of gestational age), while the remaining were during the second trimester (13 to 26 weeks) with 12.9% (n = 21), and the first trimester (first 12 weeks), with 11.0% (n = 18). For 1.8% (n = 3) the gestational age was not specified. Among postpartum MNM, more than half (55.1%, n = 49) occurred within 24 hours after delivery, and 19.1% (n = 17) within the first week after delivery (**Figure 5.6**).

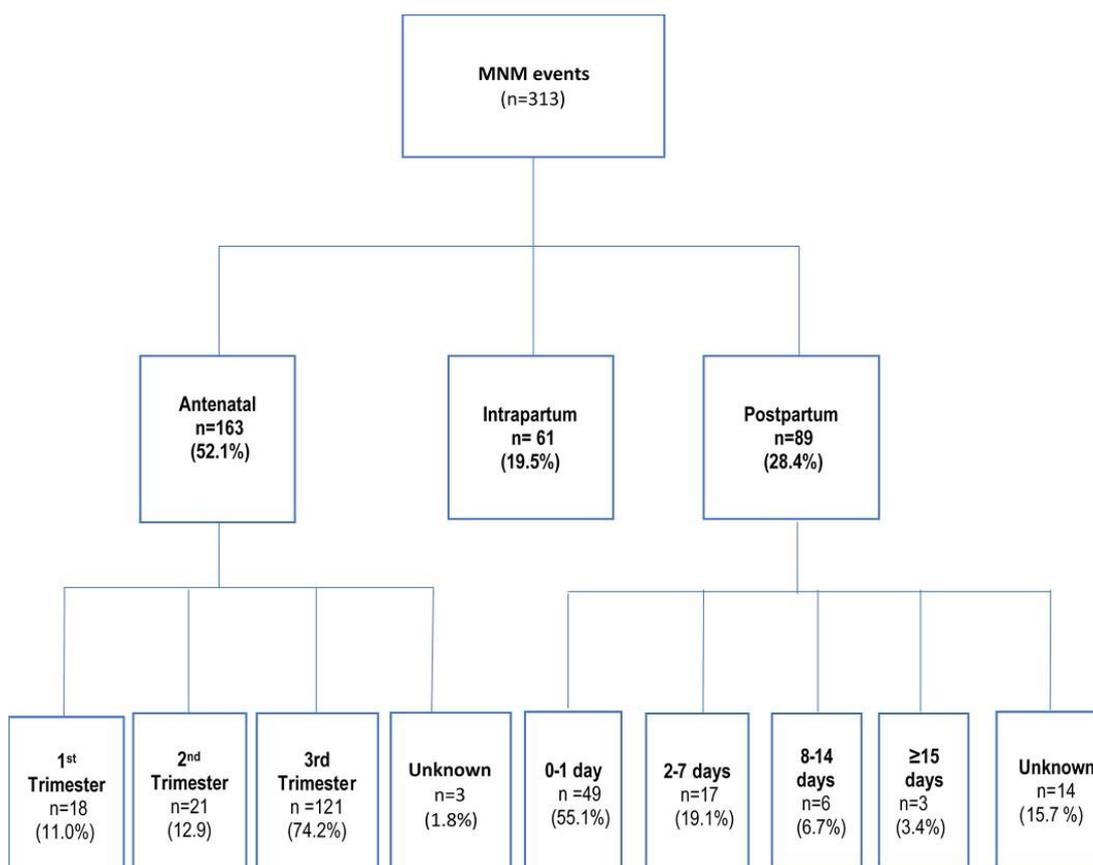


Figure 5.6: Timing of occurrence of MNM events in relation to pregnancy stage

More than half (58.3%, n = 95) of all antenatal MNM events were due to hypertensive disorders of pregnancy, and around a quarter (23.3%, n = 38) were related to non-obstetric complications (Figure 5.7). As expected, the major cause during the intrapartum period was obstetric haemorrhage (62.3%, n = 38), while for postpartum period hypertensive disorder was the leading cause (36%, n = 32), followed by obstetric haemorrhage (28.1%, n = 25).

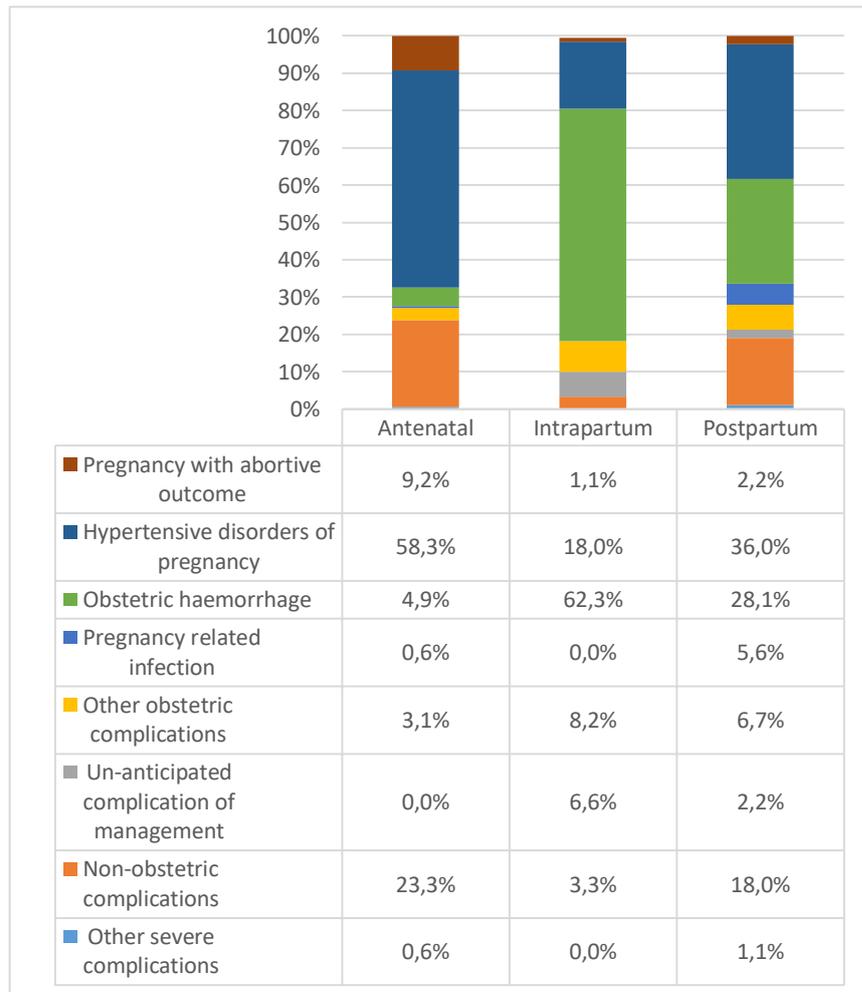
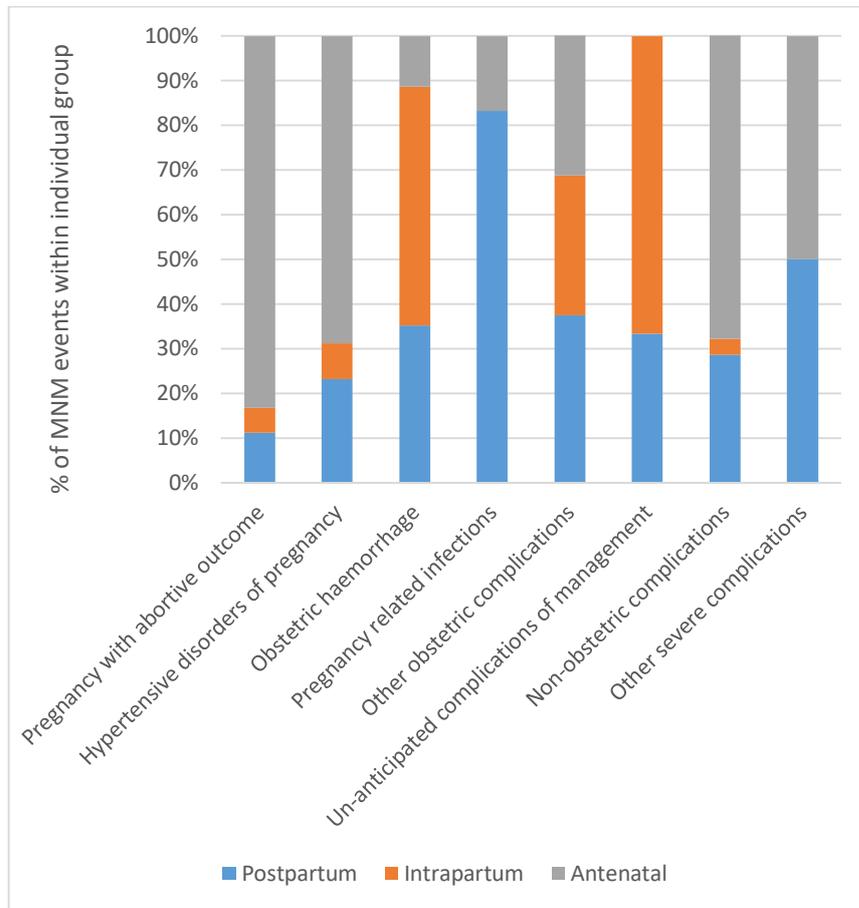


Figure 5.7: Distribution of causes of MNM events by stage of pregnancy

Examining the onset of MNM events within the individual ICD-MM group showed that the majority of MNM events during the antenatal period were related to: pregnancy with abortive outcome (83.3%, n = 15), hypertensive disorders of pregnancy (68.8%, n = 95), and non-obstetric complications (67.9%, n = 38). More than half (53.5%, n = 38) of all obstetric haemorrhage events occurred during the intrapartum period, and the majority of pregnancy-related infections (83.3%, n = 5) were in the postpartum period. The events related to other obstetric complications were evenly distributed between the three stages of pregnancy. Finally, most

unanticipated complications of management occurred during the intrapartum period (66.7%, n = 4) (**Figure 5.8**).



*Figure 5.8: Onset of MNM event within individual group of underlying causes of MNM*

The highest proportion of events within each group was reported from the governorate hospitals. Pregnancy-related infection and unanticipated complications of management were recorded only in governorate and non-MoH hospitals (**Table 5.5**).

Table 5.5: Distribution of causes of MNM by type of reporting hospital

ICD-MM group	Number of reported events by type of hospital % (n)					Total (313)
	National (n = 72)	Governorate (n = 179)	District (n = 7)	Non-MoH (n = 53)	Private (n = 2)	
Pregnancy with abortive outcome	11.1 (2)	66.7 (12)	11.1 (2)	11.1 (2)	-	100 (18)
Hypertensive disorders related to pregnancy	21.7 (30)	57.2 (79)	2.9 (4)	18.1 (25)	-	138 (100.0)
Obstetric haemorrhage	29.6 (21)	54.9 (39)	1.4 (1)	11.3 (8) (11.3)	2.8 (2)	100 (71)
Pregnancy-related infections	-	83.3 (5)	-	16.7 (1)	-	100 (6)
Other obstetric complications	-	83.3 (5)	-	16.6 (1)	-	100 (6)
Unanticipated complications of management	21.4 (12)	55.4 (31)	-	23.2 (13)	-	100 (56)
Non-obstetric complications	-	50.0 (1)	-	50.0 (1)	-	100 (2)
Other severe complications	-	50.0 (1)	-	50.0 (1)	-	100 (2)
Total	72	179	7	53	2	313

## 5.4. Causes of MNM and interventions received during hospitalisation

### 5.4.1. Admission to ICU and HDU

During the 313 MNM events, 48.6% (n = 152) of the women were admitted to ICU, 85.0% of them (266) were admitted to HDU, and 40.3% (n = 126) were admitted to both ICU and HDU. The length of ICU admission ranged from less than a day to 49 days, with a median of 2.0 (IQR = 1-3) days. For HDU, the range was between one to 28 days, with a median of 3.0 (IQR = 2-4) days. Information was not available regarding ICU admission for eight cases (5.3%), and HDU admission for 38 (14.8%) (Figure 5.9).

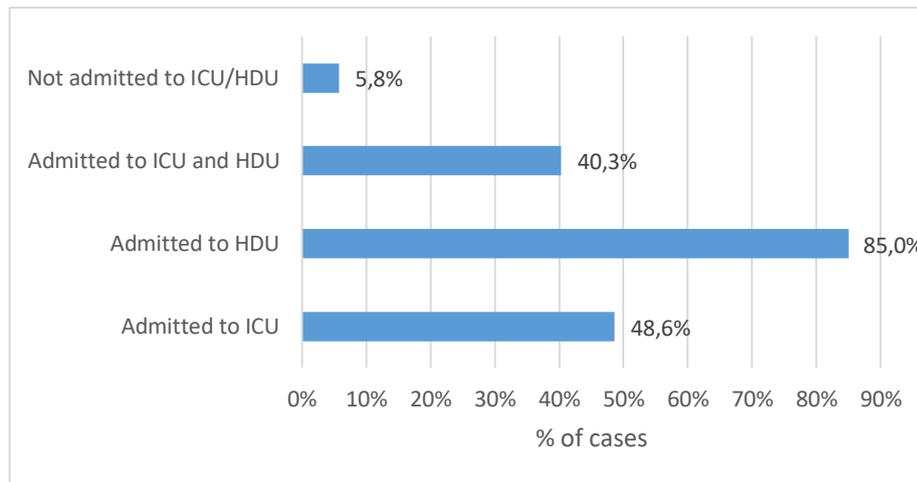


Figure 5.9: Admission of women with MNM to ICU and HDU

The highest admission rate was observed in the national and governorate hospitals, where more than half of women with MNM were admitted to the ICU (**Table 5.6**).

Table 5.6: Distribution of MNM admission to ICU and HDU by category of reporting hospital

Reporting hospital	No. hospital with ICU unit	No. MNM	Admitted to ICU % (n)	Admitted to HDU % (n)
MoH-national (n = 2)	2	72	56.9 (41)	88.7 (63)
MoH-governorate (n = 10)	10	179	57.2 (95)	88.0 (154)
MoH-district (n = 5)	4	7	14.3 (1)	42.9 (3)
Non-MoH (3)	3	53	28.3 (15)	86.5 (45)
Private	2	2	-	50.0 (1)

When the ICU admission was analysed by the group of underlying causes, the highest ICU admission rate was observed within the group of unanticipated complications of management and the group of other severe complication, with 100% admission rate, followed by the group of other obstetric complications, with 81.3% (n = 13). The lowest admission rate was recorded in the group of pregnancy-related infection and hypertensive disorders of pregnancy, with 33.3% (n = 2) and 35.5% (n = 49) respectively (**Table 5.7**).

Table 5.7: Interventions received by mothers with MNM by group of ICD-MM

ICDM Group	Admitted to ICU	Admitted to HDU	Had surgery	Received blood transfusion
	% (n) of cases within the group of ICD-MM			
Pregnancy with abortive outcome (n = 18)	38.9 (7)	88.9 (16)	88.9 (16)	100.0 (18)
Hypertensive disorder related to pregnancy (n = 138)	35.5 (49)	82.6 (114)	65.2 (90)	17.0 (28)
Obstetric haemorrhage (n = 71)	57.7 (41)	85.9 (61)	93.0 (68)	100.0 (71) (100.0)
Pregnancy-related infection (n = 6)	33.3 (2)	100.0 (6)	50.0 (3)	66.7 (4)
Other obstetric complications (n = 16)	81.3 (13)	87.5 (14)	68.8 (11)	43.8 (7)
Unanticipated complication of management (n = 6)	100.0 (6)	66.7 (4)	100.0 (6)	1 (16.7)
Non-obstetric complications (n = 56)	57.1 (32)	87.5 (49)	55.4 (31)	62.5 (35)
Other severe complications (n = 2)	100.0 (2)	100.0 (2)	100.0 (2)	50.0 (1)

#### 5.4.2. Surgical intervention

During the 313 MNM events, 71.9% (n = 225) of women had surgery, with more than half of women within each individual group having at least one surgical intervention (Table 5.7). In total, 271 surgeries were carried out among these women; in 78.2% (n = 176) of cases this was caesarean section, and in 12.4% (n = 28) it was hysterectomy (Figure 5.10).

#### 5.4.3. Transfusion of blood or blood products

More than half of MNM (52.9%, n = 165) received a transfusion of blood or blood products. The highest transfusion rate was within the groups “obstetric haemorrhage” and “pregnancy with abortive outcome”, with 100% transfusion rates (Table 5.7).

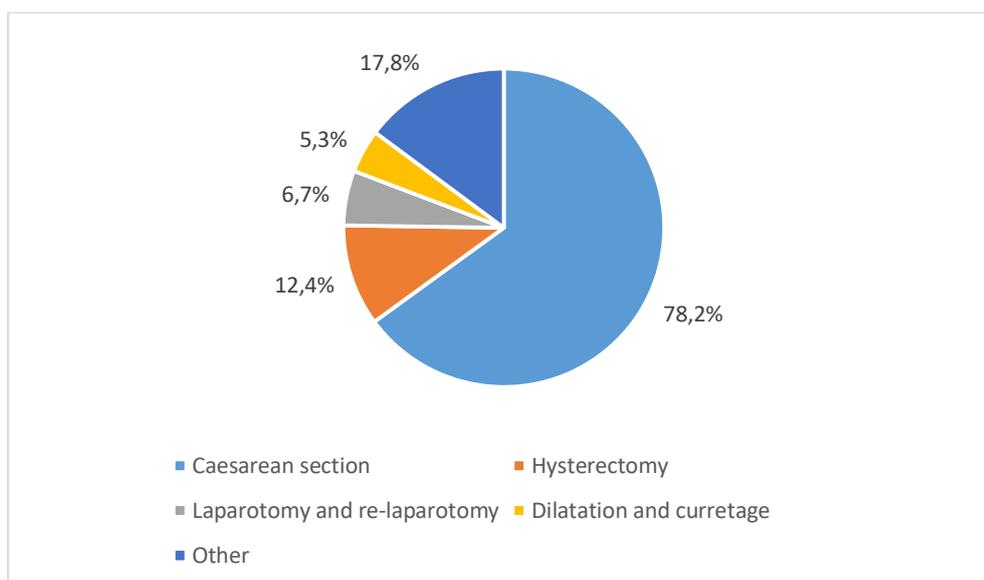


Figure 5.10: Surgical operation in cases of MNM

## 5.5. Mode of delivery and pregnancy outcome

Of the 312 women with MNM, 8.0% (n = 25) were discharge during antenatal period from the admission with the MNM events, 84.6% (n = 264) gave birth, and 7.4% (n = 23) lost their pregnancy before 24 weeks of gestation. Out of these, 52.2% (n = 12) had a miscarriage, 26.1% (n = 6) had an ectopic pregnancy, and the remaining 21.7% (n = 5) had a termination of pregnancy. Of the 264 women who gave birth, 99.2% (n = 262) had hospital delivery and over half (55.3%, n = 146) had an emergency caesarean section (**Table 5.8**)

*Table 5.8: Mode of delivery for women with MNM who gave birth*

Mode of delivery	Frequency	% of cases
Emergency caesarean section	146	55.3
Spontaneous vaginal delivery	41	15.5
Elective caesarean section	31	11.7
Induced vaginal delivery	24	9.1
Caesarean section with hysterectomy	13	4.9
Assisted delivery	9	3.4
Total women who gave birth	264	100.0

77.6% of the women who gave birth (n = 242) had live births, 6.4% (n = 20) had stillbirths, and one woman had a twin pregnancy, which ended in one live birth and one stillbirth. Perineal outcome was not specified for one woman. The stillbirth rate was 8.6%. The highest proportion of stillbirth was among the group of hypertensive disorders (**Table 5.9**).

*Table 5.9 Pregnancy outcome for mothers with MNM*

ICD-MM group	Women giving birth during admission with MNM events % (n)	Women giving live birth % (n)	Women having stillbirths % (n)
Hypertensive disorders of pregnancy (n = 138)	95.7 (132)	90.0 (119)	10 (13)
Obstetric haemorrhage (n = 71)	100.0 (71)	91.5 (65)	8.5 (6)
Pregnancy-related infection (n = 5) <sup>5</sup>	80.0 (4)	100.0 (4)	-
Other obstetric complications (n = 16)	68.8 (11)	90.0 (10)	10 (1)
Unanticipated complications of management (n = 6)	100.0 (6)	100.0 (6)	-
Non-obstetric complications (n = 56)	67.9 (38)	100.0 (38)	-
Other severe complications (n = 2)	100.0 (2)	50.0 (1)	50 (1)
Total	264		243

<sup>5</sup> The mother who had two MNM events was counted once under the group of obstetric haemorrhage.

## 5.6. Chapter summary

Using the ICD-MM classification of deaths during pregnancy, childbirth, and the puerperium, the leading underlying cause of MNM attributed by healthcare providers were to group of hypertensive disorders of pregnancy (44.1%, n = 138), obstetric haemorrhage with 22.7% (n = 71) and, non-obstetric complications with 17.9% (n = 56) of MNM events.

Severe pre-eclampsia was the most common assigned specific cause of MNM events, identified in 21.7% (n = 68) of the events, followed by eclampsia (19.5%, n = 61), HELLP syndrome (11.5%, n = 36), and SCD crisis (9.6%, n = 30). The leading causes of MNM events were also the main causes for PLTC and maternal deaths. The leading cause for PLTC was obstetric haemorrhage (51%, n = 723), followed by hypertensive disorders of pregnancy (27.7%, n = 393). Most maternal deaths were due to non-obstetric complications (48.0%, n = 12) followed by other obstetric complications, hypertensive disorders (12.0%, n = 3) and obstetric haemorrhage (12.0%, n = 3).

The highest proportion of MNM events occurred during the antenatal period (52.1%, n = 163), followed by the postpartum (28.4%, n = 89) then the intrapartum (19.5%, n = 61) periods. The majority (74.2%, n = 127) of antenatal events occurred during the third trimester, and 55% (n = 95) of postpartum MNM events occurred within the 24 hours after delivery. The leading cause for the antenatal and postpartum MNM events was hypertensive disorders of pregnancy, with 58.3% (n = 95) and 36% (n = 32) of all events, respectively. Obstetric haemorrhage was the most common cause for the intrapartum MNM events, with 62.3% (n = 38).

When the causes of MNM were analysed by type of reporting hospital, the highest proportion of cases within each group was reported from the governorate hospitals.

Around half of all women with MNM (48.6%, n = 152) were admitted to ICU. The length of ICU admission ranged from less than a day to 49 days, with a median of 2.0 (IQR 2) days. The groups of unanticipated complications of management and other severe complication had the highest admission rates, with 100%, whereas the lowest rates were observed in the groups pregnancy-related infection and hypertensive disorders of pregnancy, with 33.3% (n = 2) and 35.5% (n = 49), respectively.

During the 313 MNM events, a total of 271 surgeries were performed in 71.8% (n=224) of women, with more than half of all women in each group for the underlying cause of MNM having a surgical operation. Caesarean section was the most common surgery (78.2%, n = 176), followed by hysterectomy (12.4%, n = 28). More than half (52.9%, n = 165) of women with MNM received a transfusion of blood or blood products.

Of the 312 women with MNM, 84.6% (n = 264) gave birth and 7.4% (n = 23) lost their pregnancy before 24 weeks of gestation. Nearly all women (99.2%, n = 262) who gave birth had a hospital delivery, and over half (55.3%, n = 146) had an emergency caesarean section. Most of them (77.6%, n = 242) had live births, with only 6.4% (n = 20) had stillbirths.

## 6. Causes of and Conditions Contributing to MNM According to Review Committees

This chapter focuses on answering the following research questions:

- What are the underlying causes of MNM?
- What are the contributory conditions to MNM?

It is presented in six sections. The first section reports on the number of MNM events reviewed by reviewers at the four levels of review; hospital, regional, national and international. The second part presents the underlying causes assigned by each group of reviewers. A comparison between these assigned causes with level of agreement is described also. Sections four and five present and compare the contributory conditions to MNM as identified by the reviewers. The last section summarises the main findings presented in the chapter.

### 6.1. MNM events reviewed at different levels

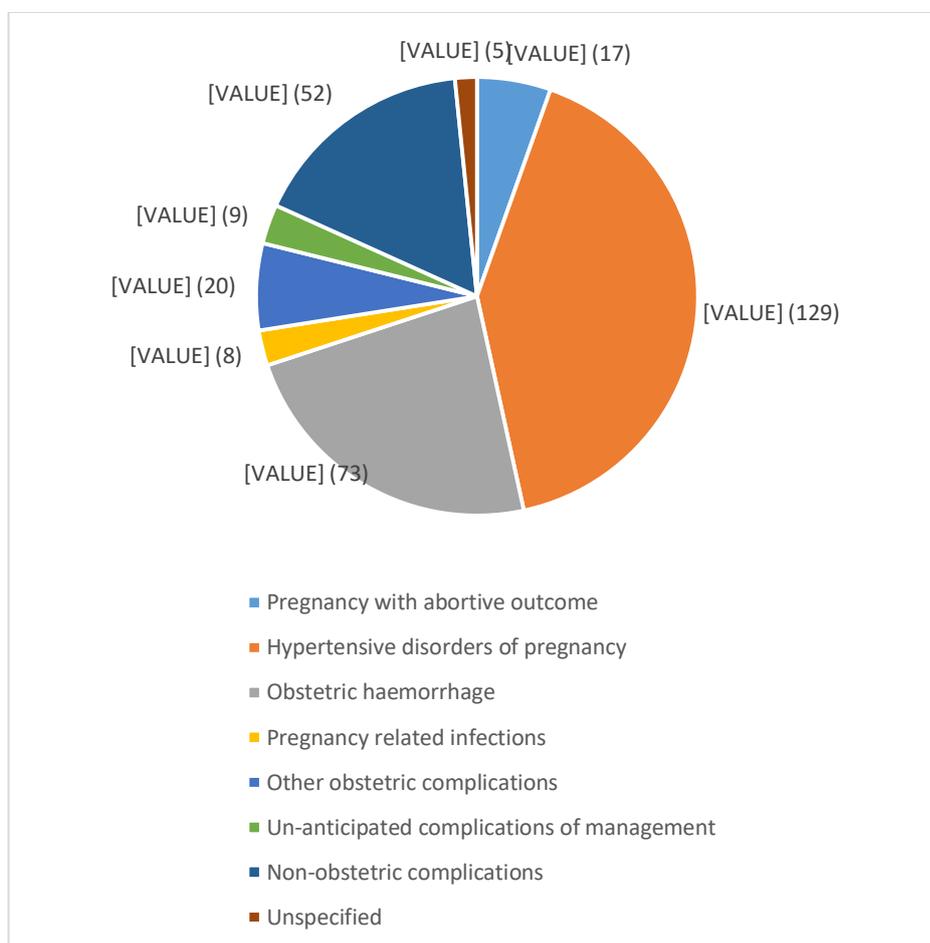
The reviewers at the hospital level reviewed all 313 identified MNM events (100%). The Regional Maternal Mortality Committees reviewed 290 (92.7%). Out of the 313 MNM events, 156 (50%) were selected using a systematic sampling technique, ensuring representation from all governorates for review by the National Maternal Mortality Committee and the International Expert Review Panel. All the 156 events (100%) were subsequently reviewed by both committees.

### 6.2. Underlying cause of MNM assigned by reviewers at different levels

#### 6.2.1. Underlying causes assigned by assessors at the hospital level

Like the results obtained by healthcare providers presented in chapter 5, the reviewers at hospital level assigned hypertensive disorders of pregnancy as the leading cause of MNM, with 41.2% (n = 129) of all events, Obstetric haemorrhage accounted for 23.3% (n = 73), and non-obstetric complications for 16.6% (n = 52). Other obstetric complications accounted to 6.4% (n = 20), and pregnancy with abortive outcome for 5.4% (n = 17). Groups accounting for less than 5% included

unanticipated complications of management (2.9%, n = 9) and pregnancy-related infections (2.6%, n = 8). 1.6% (n = 5) of the events were not assigned to any ICD-group of underlying causes (**Figure 6.1**).



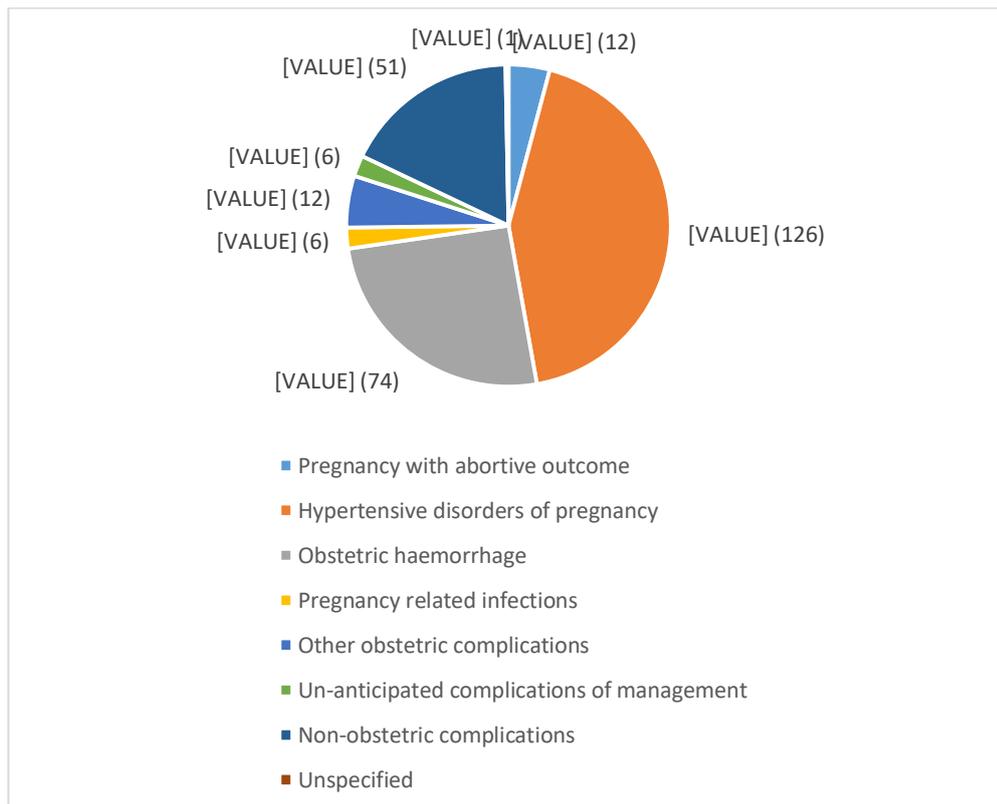
*Figure 6.1: Underlying causes of MNM by ICD-MM groups as assigned by assessors at the hospital level (n = 313)*

Of the 313 MNM events, severe pre-eclampsia was the most common assigned specific cause, and accounting for 13.4% (n = 42) of the MNM events, followed by SCD with 9.6% (n = 30) and eclampsia with 8.9% (n = 28). The morbidly adherent placenta accounted for 7.3% (n = 23), and eclampsia with severe pre-eclampsia accounted for 6.7% (n = 21). The rest of the specific causes accounted for less than 5% of all MNM events (**Annex 13**).

### **6.2.2. Underlying causes as assigned by the Regional Maternal Mortality Committee**

The Regional Maternal Mortality Committee reviewed 290 MNM events, of which 43.4% (n = 126) were categorised as hypertensive disorders of pregnancy, 25.5% (n

= 74) under obstetric haemorrhage, and 17.6% (n = 51) under non-obstetric complications. The group of other obstetric complications accounted for 5.2% (n = 15) of events. Less than 5% of all MNM events were assigned to other ICD groups (**Figure 6.2**). Specific causes included eclampsia (14.8%, n = 43), severe pre-eclampsia (10.7%, n = 31), and HELLP syndrome (7.2%, n = 21). SCD accounted for 8.6% (n = 25) of all MNM events. The other specific causes were assigned for less than 5% of all MNM events (**Annex 14**).



*Figure 6.2: Underlying causes of MNM as assigned by reviewers at the regional level (n = 290)*

Some inconsistency in the classification of MNM events by ICD-MM groups was observed. The committee categorised specific causes related to ruptured ectopic pregnancy, morbidly adherent placenta, eclampsia, and peripartum cardiomyopathy under two different groups.

Ruptured ectopic pregnancy was attributed to three events, two of them were classified under the group of pregnancy with abortive outcome, and one under obstetric haemorrhage. Eclampsia was assigned to 43 MNM events, 42 of them were categorised under the group of hypertensive disorders of pregnancy, and one under other obstetric complications.

Nine events related to morbidly adherent placenta were categorised as obstetric haemorrhage, and one event was listed under the group of other obstetric complications. Events related to SCD and peripartum cardiomyopathy were categorised as other obstetric complications and non-obstetric complications (Annex 14).

### 6.2.3. Underlying causes as assigned by the National Maternal Mortality Committee

From reviewing 156 MNM events, the National Maternal Morality Committee also assigned the group of hypertensive disorders as a leading cause of MNM events with 41.7%, followed by obstetric haemorrhage (27.6%, n = 43) and non-obstetric complications (18.6%, n = 29). The rest of the groups accounted for less than 5% of the MNM events (Figure 6.3).

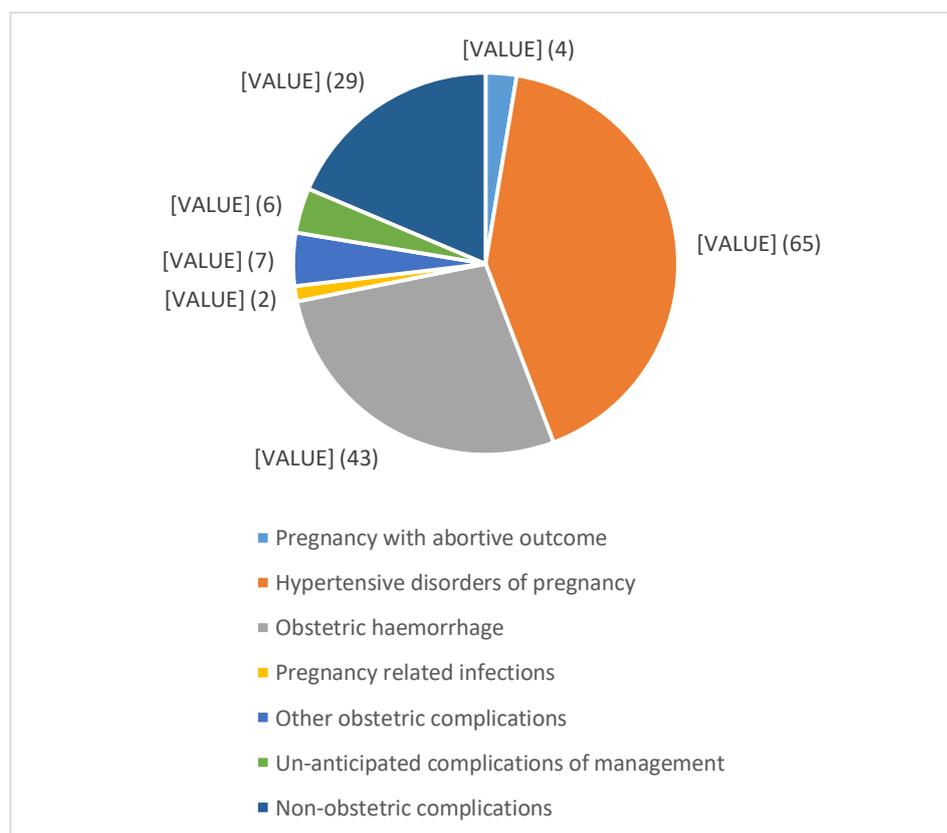


Figure 6.3: Underlying causes of MNM as assigned by reviewers at the national level (n = 156)

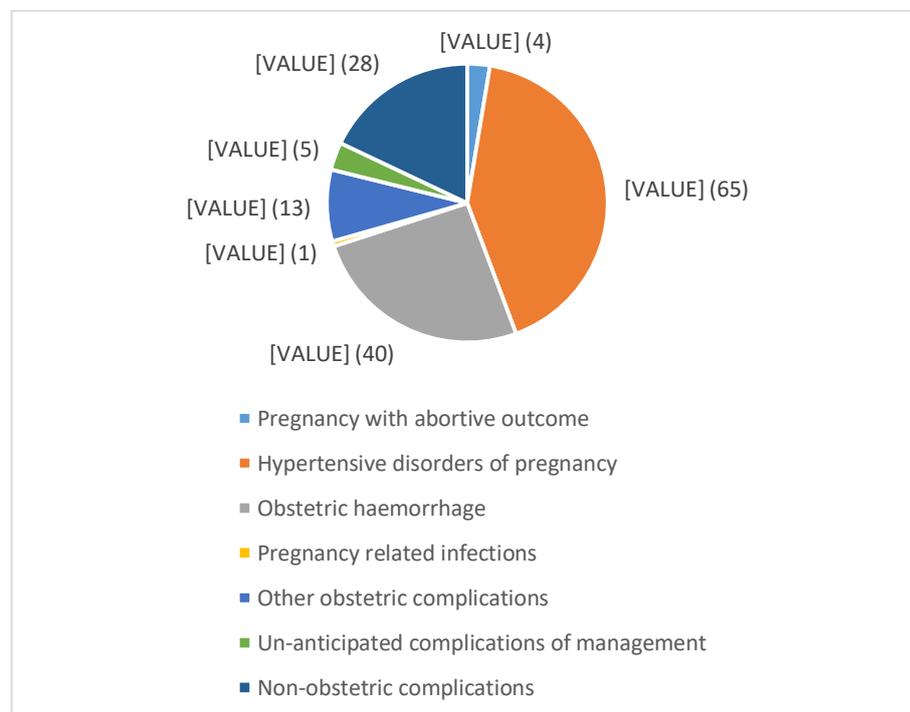
Eclampsia was the most commonly attributed specific cause with 15.4% (n = 24) followed by SCD (10.3%, n = 16), severe pre-eclampsia (9.6%, n = 15) and HELLP

syndrome (5.8%, n = 9). The rest of the specific causes were assigned to less than 5% of the events (**Annex 15**).

Similar to the observation noted earlier under the regional review, the National Committee recorded ectopic pregnancy under the group of pregnancy with abortive outcome as well as under the group of obstetric haemorrhage. Peripartum cardiomyopathy was categorised as other obstetric complication (n = 2) as well as non-obstetric complication (n = 3).

#### 6.2.4. Underlying causes as assigned by the International Expert Panel

The leading group of causes assigned by the International Expert Panel were similar to the causes assigned by the National Committee (**Figure 6.4**). The group of hypertensive disorders of pregnancy was the most common cause, with 41.7% (n = 65), followed by obstetric haemorrhage with 25.6% (n = 40), and non-obstetric complications with 17.9% (n = 28). Other obstetric complications were assigned to 8.3% (n = 13). The three leading specific causes were eclampsia (9.6%, n = 15), SCD disease (9.0%, n = 14), and severe pre-eclampsia with HELLP syndrome (7.7%, n = 12) (**Annex 16**).



*Figure 6.4: Underlying causes of MNM as assigned by the reviewers at the international level*

Similar to the Regional and the National Maternal Mortality Committees, the expert group listed one event with ruptured ectopic pregnancy under the group of pregnancy with abortive outcome and one under obstetric haemorrhage. Two events related to complications of anaesthesia were categorised as other obstetric complications.

### **6.3. Comparison of assigned underlying causes of MNM as identified at each of the four levels**

This section compares the underlying causes of MNM as assigned by reviewers at different levels. The 156 MNM events reviewed at all four levels were selected for comparison. The first three leading group of causes were similar: hypertensive disorders of pregnancy, obstetric haemorrhage, and non-obstetric complications. Around 40.0% of the 156 MNM were attributed to hypertensive disorders of pregnancy. Obstetric haemorrhage was assigned to around a quarter of the events, and non-obstetric complications to around a third (**Figure 6.5**).

There was generally marked agreement, but variation was observed in the distribution of groups of other obstetric complications and unanticipated complications of management. The International Expert Panel attributed more events to the group of other obstetric complications compared to in-country reviewers, with 8.3% compared to around 5.0%. The number of events attributed to unanticipated complications of management by the Regional Committee was almost half the number (1.9%, n = 3) assigned by other reviewers (3.8%, n = 6).

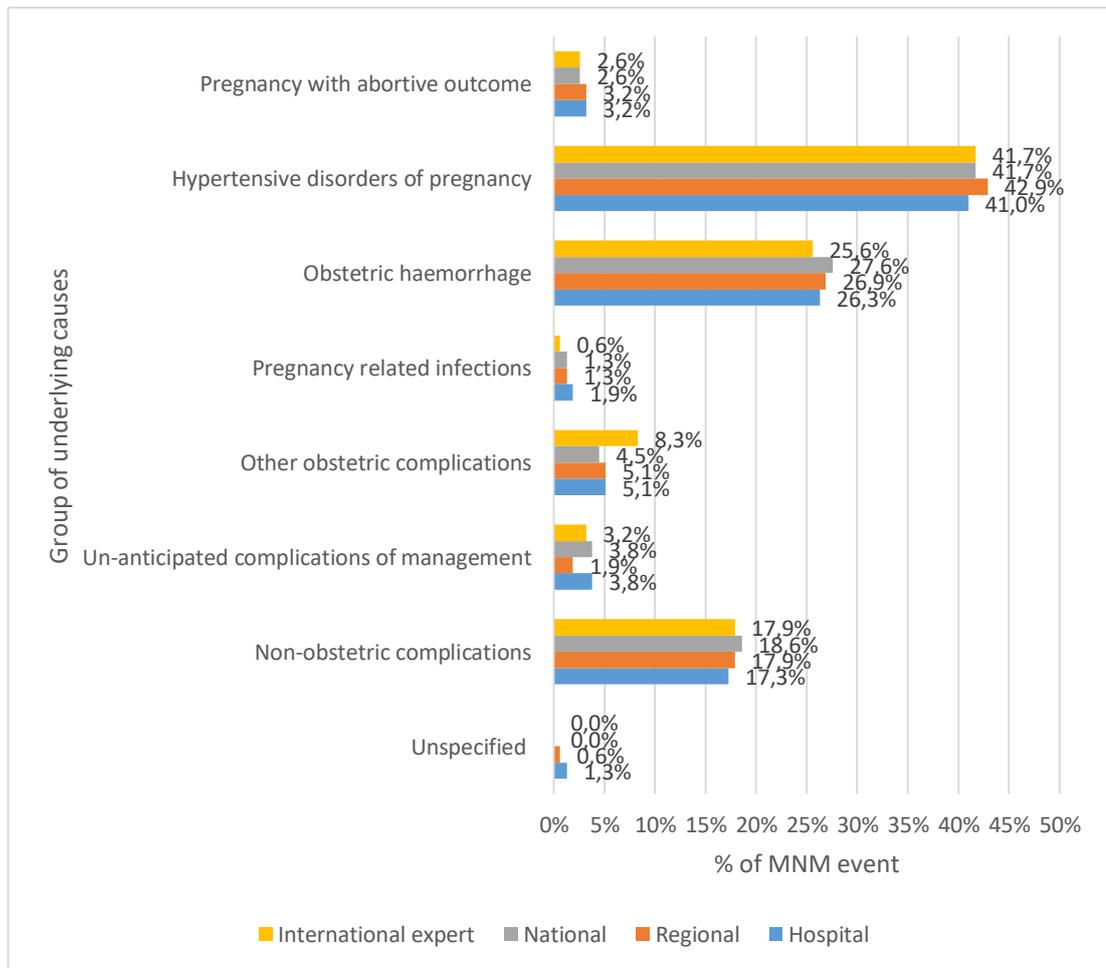


Figure 6.5: Comparison of underlying causes of MNM assigned by reviewers at different levels of review

### 6.3.1. Comparing the assigned specific causes by different reviewers

The first three leading specific causes were also almost similar across the four levels of review, with minor variation in the order of these causes. Hospital and regional reviewers assigned severe pre-eclampsia as a leading specific cause with 13.5% (n = 21) and 12.8% (n = 20) of all 156 MNM events, respectively. Eclampsia was the second most attributed cause (12.2%, n = 19 and 10.9%, n = 17), followed by SCD (10.3%, n = 16 and 8.3%, n = 13). For the National and International Expert Panels, eclampsia was the most common attributed cause with 15.4% (n = 24) and 9.6% (n = 15), respectively, followed by SCD crisis (10.3%, n = 16; 9.0%, n = 14) and severe pre-eclampsia (9.6%, n = 15; 7.1%, n = 11).

Morbidly adherent placenta was slightly more often attributed by reviewers at the hospital, national, and international levels compared to regional reviewers (around 5.1% versus 3.8%). International and national reviewers were able to specify more causes of all MNM events compared to hospital and regional reviewers, with no

“unspecified cause” for any MNM by national and international reviewers. It was also observed that the regional reviewers had more MNM events with unspecified cause compared to other reviewers, with the highest unspecified causes were among hypertensive disorders and obstetric haemorrhage (**Table 6.1**).

*Table 6.1: Specific causes of MNM assigned by reviewers at different levels of review (n = 156)*

Group/ specific cause	Reviewer Level % (n)			
	Hospital	Regional	National	Expert
Pregnancy with abortive outcome	3.2 (5)	100.0 (2)	2.6 (4)	2.6 (4)
Ruptured ectopic pregnancy	1.3 (2)	0.6 (1)	0.6 (1)	1 (0.6)
Severe infection/ sepsis	0.6 (1)	0.6 (1)	1.3 (2)	1.3 (2)
Incomplete abortion with haemorrhage	0.6 (1)	0.6 (1)	0.6 (1)	-
Sepsis with cardiomyopathy	0.6 (1)	-	-	-
Induced abortion	-	10.6 (1)	-	-
Unspecified	-	0.6 (1)	-	0.6 (1)
<b>Hypertensive disorders of pregnancy</b>	<b>41.0 (64)</b>	<b>42.9 (67)</b>	<b>41.7 (65)</b>	<b>41.7 (65)</b>
Eclampsia	19 (12.2)	17 (10.9)	24 (15.4)	15 (9.6)
Severe pre-eclampsia	21 (13.5)	20 (12.8)	15 (9.6)	11 (7.1)
HELLP syndrome	13 (8.3)	10 (6.4)	9 (5.8)	4 (2.6)
Eclampsia and severe pre-eclampsia	1.3 (2)	0.6 (1)	0.6 (1)	5 (3.2)
Eclampsia and HELLP syndrome	3 (1.9)	1 (1.9)	3 (6.4)	2 (1.3)
Severe pre-eclampsia and HELLP syndrome	1.3 (2)	3 (1.9)	10 (6.4)	12 (7.7)
Hypertension with pulmonary oedema	1 (0.6)	3 (1.9)	1.3 (2)	0.6 (1)
Pregnancy induced hypertension	3 (1.9)	-	-	1.3 (2)
SLE and anti-phospholipid syndrome	-	-	-	1.3 (2)
Chronic hypertension with peripartum cardiomyopathy	-	-	-	0.6 (1)
Concentric left ventricular hypertrophy secondary to hypertension	-	-	-	0.6 (1)
Essential (chronic) hypertension	-	-	-	0.6 (1)
Intrapartum pregnancy induced hypertension with haemorrhage	-	-	-	0.6 (1)
Low platelets with risk of HELLP syndrome	-	-	-	0.6 (1)
Postnatal hypertension with altered renal function	-	-	-	0.6 (1)
Pregnancy-induced hypertension with elevated liver enzymes and creatinine, and haemolysis	-	-	0.6 (1)	0.6 (1)
Unspecified	-	6.4 (10)	-	2.6 (4)

Group/ specific cause	Reviewer Level % (n)			
	Hospital	Regional	National	Expert
Obstetric haemorrhage	26.3 (41)	26.9 (42)	27.6 (43)	25.6 (40)
Morbidly adherent placenta	5.1 (8)	3.8 (6)	7 (4.5)	5.1 (8)
Placenta previa	3.8 (6)	1.9 (3)	1.3 (2)	3.8 (6)
Placental abruption	2.6 (4)	1.3 (2)	2.6 (4)	3 (1.9)
Obstetric trauma	3.2 (5)	3 (1.9)	2.6 (4)	4.5 (7)
Uterine atony	1.3 (2)	3 (1.9)	3 (1.9)	0.6 (1)
Surgical haemorrhage (During caesarean section and hysterectomy)	2.6 (4)	1 (0.6)	3 (1.9)	-
Uterine atony and traumatic postpartum haemorrhage	3 (1.9)	1 (0.6)	3 (1.9)	-
Uterine rupture	1.3 (2)	-	1.3 (2)	-
Obstructed labour	0.6 (1)	-	-	-
Cervical tear	0.6 (1)	-	-	-
Retained placenta	0.6 (1)	-	-	-
Cervical tear and uterine atony	-	-	-	0.6 (1)
Secondary postpartum haemorrhage due to anticoagulant drug	0.6 (1)	-	0.6 (1)	-
Secondary postpartum haemorrhage	-	0.6 (1)	0.6 (1)	0.6 (1)
Antepartum haemorrhage with coagulation defect	-	0.6 (1)	-	-
Uterine atony, vascular bleeding and broad ligament haematoma	-	-	-	0.6 (1)
Ruptured ectopic pregnancy	-	-	0.6 (1)	0.6 (1)
Pelvic haematoma, unspecified the cause	-	2 (1.3)	2 (1.3)	-
Unspecified	1 (0.6)	11.5 (19)	5.8 (9)	5.8 (9)
Pregnancy-related infection	1.9 (3)	1.3 (2)	1.3 (2)	0.6 (1)
Pelvic collection with sepsis	-	-	0.6 (1)	-
Infection complicating caesarean hysterectomy	0.6 (1)	-	-	-
Sepsis induced myocarditis	0.6 (1)	-	-	-
Purpureal sepsis with haemolytic uremic syndrome	-	0.6 (1)	1 (0.6) 0.6 (1)	-
Sepsis	0.6 (1)	0.6 (1)	-	-
Purpureal sepsis	0.6 (1)	-	-	-
Unspecified	-	-	-	1 (0.6)
Other obstetric complications	8 (5.1)	8 (5.1)	7 (4.5)	13 (8.3)
Uterine rupture	-	0.6 (1)	0.6 (1)	1.3 (2)
Peripartum cardiomyopathy	3 (1.9)	-	1.3 (2)	1.3 (2)
Pulmonary embolism	1.3 (2)	1.3 (2)	2 (1.3)	1.3 (2)
Peripartum cardiomyopathy with fluid overload	-	-	-	0.6 (1)
Obstetric trauma	1.3 (2)	1.3 (2)	1.3 (2)	1.3 (2)
Gestational thrombocytopenia with pulmonary oedema	-	-	-	0.6 (1)
Haemolytic uraemic syndrome	-	-	-	0.6 (1)
HELLP syndrome, possible acute fatty liver	-	-	-	0.6 (1)
hyperemesis gravidarum leading to Wernicke's encephalopathy	0.6 (1)	0.6 (1)	0.6 (1)	0.6 (1)
Postpartum eclampsia	-	0.6 (1)	-	-
Unspecified	-	0.6 (1)	-	-
Unanticipated complications of management	6 (3.8)	1.9 (3)	6 (3.8)	5 (3.2)
Complications related to anaesthesia	1.9 (3)	1.9 (3)	4 (2.6)	1.3 (2)
Life threatening transfusion reaction after receiving ABO incompatible blood during elective C section	0.6 (1)	-	0.6 (1)	0.6 (1)
Fluid overload	0.6 (1)	-	0.6 (1)	-

Group/ specific cause	Reviewer Level % (n)			
	Hospital	Regional	National	Expert
Artificial membrane rupture caused cord prolapse and severe obstetric haemorrhage	-	-	-	0.6 (1)
Cardiac condition predisposing to pulmonary oedema	-	-	-	0.6 (1)
Fluid overload and cardiomyopathy	1 (0.6)	-	-	-
Non-obstetric complications	17.3 (27)	17.9 (28)	18.6 (29)	17.9 (28)
Sickle cell disease	16 (10.3)	13 (8.3)	16 (10.3)	14 (9.0)
Cardiac disease	1.3 (2)	1.9 (3)	1.3 (2)	0.6 (1)
Epilepsy	0.6 (1)	-	0.6 (1)	0.6 (1)
Myasthenia gravis	0.6 (1)	-	0.6 (1)	0.6 (1)
Diabetic Keto-acidosis	0.6 (1)	-	0.6 (1)	0.6 (1)
Renal disease	-	0.6 (1)	0.6 (1)	0.6 (1)
Anaemia	0.6 (1)	0.6 (1)	0.6 (1)	-
Ruptured cerebral aneurysm-subarachnoid haemorrhage	-	-	1 (0.6)	1 (0.6)
Bleeding from left adnexa	0.6 (1)	-	-	1 (0.6)
Peripartum cardiomyopathy	-	1.3 (2)	1.9 (3)	-
Complications of anaesthesia	-	-	-	1.3 (2)
Sickle cell disease with peripartum cardiomyopathy	-	-	-	0.6 (1)
Sickle cell Disease and SLE with severe pre-eclampsia and vitamin B12 deficiency	-	-	-	0.6 (1)
SLE	-	-	0.6 (1)	-
Severe hypertension and SLE	0.6 (1)	-	-	-
Left MCA thrombus led to right-sided CVA	-	-	-	0.6 (1)
Stroke	0.6 (1)	-	-	-
Cavernous haemangioma	-	0.6 (1)	-	-
Convulsion related to hypocalcaemia and hypoparathyroidism	-	-	-	0.6 (1)
Acute postpartum pulmonary oedema	-	-	-	0.6 (1)
Thrombotic thrombocytopenic purpura	0.6 (1)	-	-	-
Non-obstetric haemorrhagic shock, unspecified	-	0.6 (1)	-	-
Unspecified	3.8 (6)	0.6 (1)	-	-
Unspecified	1.3 (2)	-	-	-

### 6.3.2. Level of agreement between different reviewers

Further analysis was conducted to compare the level of agreement between different reviewers in assigning the underlying cause by measuring Cohen's kappa coefficient ( $\kappa$ ) on the assigned ICD-group of causes. The 153 MNM events to which the reviewers at all levels had assigned ICD-groups were selected to calculate the  $\kappa$  value.

**Table 6.2** summarises the obtained results on the number and percentage of MNM events in which group of reviewers agreed with  $\kappa$  value. In general, based on Landis and Koch (1977), there was almost perfect agreement in assigning ICD-group of causes was observed between hospital and regional reviewers, as well as between hospital and national reviewers ( $\kappa = 0.9$ ). Also, there was a substantial

agreement between regional and national reviewers ( $\kappa = 0.8$ ). A similar level of agreement (substantial agreement with  $\kappa = 0.8$ ) was observed between different individual groups of country reviewers and the International Expert Panel.

*Table 6.2: Measure of agreement between different reviewers in assigning the underlying cause of MNM (n = 153)*

Group of reviewers	No. events (%) with agreement on assigning ICD-MM group of the underlying cause	$\kappa$ -value (95% CI)	P-value
Hospital reviewers versus regional reviewers	141 (92.2%)	0.9 (0.8;0.9)	P <0.001
Hospital reviewers versus national reviewers	144 (94.1%)	0.9 (0.8;0.9)	
Hospital reviewers versus international expert panel	136 (88.9%)	0.8 (0.7;0.8)	
Regional reviewers versus national reviewers' panel	136 (88.9%)	0.8 (0.8;0.9)	
Regional reviewers versus international expert panel	134 (87.6%)	0.8 (0.7;0.8)	
National reviewers versus international expert panel	135 (88.2%)	0.8 (0.7; 0.8)	

## 6.4. Contributory conditions

### 6.4.1. Contributory conditions assigned by reviewers at the hospital level

The reviewers at the hospital level identified contributory conditions to 68.7% (n = 215) of the 313 MNM events. Maternal conditions were the most identified conditions and were recorded in half of the events (50.2%, n = 157), followed by conditions related to the foetus (14.7%, n = 46) and interventions (12.8%, n = 40).

Obstetric conditions, including previous caesarean section and grand-multiparity, were the most commonly identified maternal conditions, with 22.4% (n = 70) and 16.6% (n = 52) of events. Other obstetric conditions contributed to less than 5% of the MNM events. Within the medical disorders, diabetes as a contributory condition was attributed to 15.0% (n = 47) of the 313 MNM events, anaemia to 14.4% (n = 45), hypertension to 5.8% (n = 18), and obesity to 3.5% (n = 11). Other medical disorders including thyroid disease, SLE, and previous history of pre-eclampsia were recorded in 13.1% (n = 41) of cases. Each of the specific conditions related to the foetus and interventions was recorded in less than 5% of the events.

Further analysis of contributory conditions by ICD-MM group of underlying causes showed that contributory conditions were identified in more than 50% of MNM

events recorded within each group of causes. The most commonly recorded conditions were for the group of obstetric haemorrhage, with 87.5% (63), and the least recorded was for the group of pregnancy with abortive outcome, with 58.8% (n = 10). Anaemia was the highest recorded contributory condition for groups of pregnancy with abortive outcome (20.4%, n = 5), followed by other obstetric complications and non-obstetric complications with equal numbers (42.6%, n = 23). Diabetes was the most common contributory condition for hypertensive disorders of pregnancy, with 18.6% (n = 24) of the events. Previous caesarean sections and grand-multiparity were the most common conditions contributed to obstetric haemorrhage, with 55.6% (n = 40) and 34.7% (n = 25) of MNM events, respectively. They also had the highest frequency recorded under the MNM events with pregnancy-related infection, with 25.0% (n = 2). Surprisingly, it was observed across all the groups of underlying causes that previous caesarean section was considered as one of the top three contributory conditions (**Annex 17**).

#### **6.4.2. Contributory conditions assigned by the Regional Maternal Mortality Committee**

The regional reviewers identified contributory conditions in 74.5% (n = 216) of the 290 MNM events. Maternal conditions were the most frequent contributing conditions (68.3%, n = 198), followed by foetal conditions (18.6%, n = 54) and interventions (9.0%, n = 26). Previous caesarean section and medical disorders were the most commonly identified conditions, with 22.4% (n = 65) and 20.0% (n = 58) respectively.

The Committee recorded the highest percentage of contributory conditions among group of other obstetric complications and obstetric haemorrhage, with 93.3% (n = 14) and 91.9% (n = 68) of the MNM events respectively. The distribution of specific contributory conditions within an individual group was almost similar to the findings of the hospital reviewers. The most common contributing conditions for obstetric haemorrhage were previous caesarean section (48.6%, n = 36) and grand multiparity (39.2%, n = 29), while the most frequently identified hypertensive disorder of pregnancy was diabetes (21.6%, n = 27). Anaemia was a major contributing condition for non-obstetric disorders, recorded in about half of the MNM events (47.1%, n = 24) (**Annex 18**).

#### **6.4.3. Contributory conditions assigned by the National Maternal Mortality Committee**

The national reviewers identified a contributory condition in 82.1% (n = 128) of the 156 MNM events reviewed at this level. Maternal conditions were recorded in 78.8% (n = 123) of the MNM events, while conditions related to the foetus and interventions were identified in only 18.6% (n = 29) and 16.0% (n = 25) of MNM events, respectively. Previous caesarean section was the leading condition, identified in more than a quarter of the 156 MNM events (26.3%, n = 41), and slightly more than half of MNM events were related to obstetric haemorrhage (53%, n = 23). Diabetes was the second most common recorded condition for the 156 MNM events, with 23.7% (n = 37), with the highest recorded figures were for obstetric haemorrhage (32.6%, n = 14) and hypertensive disorders of pregnancy (24.6% 16). Grand multiparity was attributed as a contributory condition to about one-fifth of the MNM events (21.8%, n = 34), with the highest record was for obstetric haemorrhage (44.2%, n = 19). Anaemia contributed to about one-fifth (21.2%, n = 33) of the 156 events, and to half of MNM events related to non-obstetric complications (51.7%, n = 15). Other medical disorders were assigned to 20.1% of the MNM events, and the rest of the conditions were recorded in less than 10% (**Annex 19**).

#### **6.4.4. Contributory conditions assigned by the International Expert Panel**

The international reviewers recorded contributory conditions in 61.5% (n = 96) of the 165 MNM events. Similar to other findings of other review panel, maternal conditions were the leading identified contributory conditions for MNM events (53.8%, n = 84), followed in much smaller numbers by conditions related to interventions (16.0%, n = 25) and then those related to the foetus (12.2%, n = 19). Previous caesarean section and anaemia were the most commonly identified conditions, with 16.7% (n = 26) of the events each. Previous caesarean section had the highest record within the MNM events with obstetric haemorrhage (37.5%, n = 15). Anaemia was the most common contributor to non-obstetric complications (32.1%, n = 9) and obstetric haemorrhage (17.5%, n = 7). Diabetes contributed to 14.7% (n = 23) of the 156 events and had the highest recorded frequency within the group of hypertensive disorders of pregnancy (21.5%, n = 14). Other medical disorders, grand multiparity, and obesity were identified in 21.8% (n = 20), 11.5% (n = 18), and 8.3% (n = 13) of the 156 events, respectively. The rest of the conditions were recorded in less than 10% of the MNM events (**Annex 20**).

## 6.5. Comparison of contributory conditions to MNM identified at the four levels of review

Of the 156 MNM events reviewed at the four levels of review, the reviewers identified contributory conditions in more than 50% of MNM events. The highest recorded number was by the national review panel (82.1%, n = 128), and the lowest was by the international review panel (61.5%, n = 96). Across all levels, maternal conditions were considered the major contributors to MNM events, and were collectively identified in more than 50% of all MNM events. Conditions related to the foetus were identified in less than 20% of MNM events; the lowest assigned percentage was by the international panel (12.2%, n = 19). Regarding the conditions related to interventions, the hospital, national, and international reviewers recorded these conditions in more than 10% of the events, while the regional reviewers recorded them in 7.7% (n = 12).

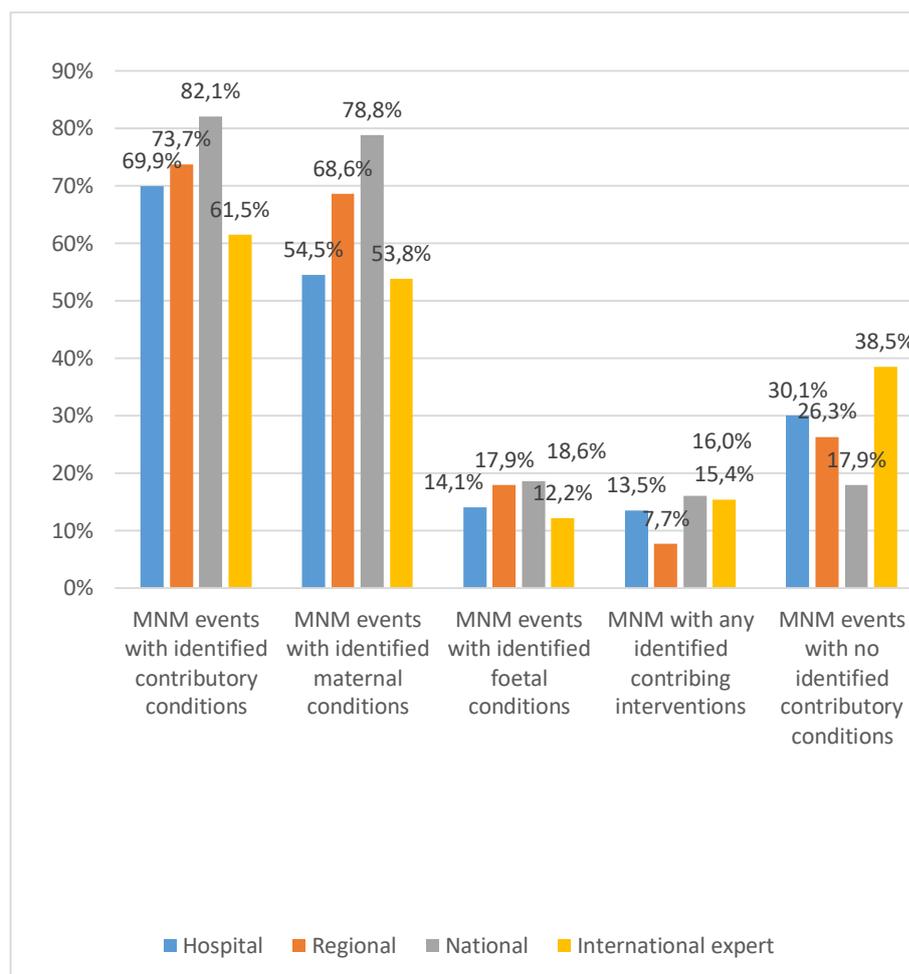


Figure 6.6: Contributory conditions identified by different review panel

Examining specific contributory conditions reveals that the leading conditions were previous caesarean section, medical disorders, and grand multiparity, with only slight variation observed between different review panels. Previous caesarean section varied between about a quarter of events for the hospital and national reviewers, to about a fifth for the regional reviewers, and less than this for the expert reviewers.

Medical disorders including anaemia, diabetes, and the group of other medical disorders were the second most common conditions identified by regional, national, and international review panels, followed by grand multiparity (**Table 6.3**). The reviewers agreed that each specific condition related to foetus or interventions contributed to less than 5.0% of the MNM events.

Table 6.3: Comparing contributory conditions identified by assessors at different levels of review

	Assessors	Regional	National	International
	% (n)			
MNM with identified contributory conditions	69.9 (109)	73.7 (115)	82.1 (128)	61.5 (96)
MNM with no identified conditions	30.1 (47)	26.3 (41)	17.9 (28)	38.5 (60)
<b>Maternal conditions</b>	<b>54.5 (85)</b>	<b>68.6 (107)</b>	<b>78.8 (123)</b>	<b>53.8 (84)</b>
Previous caesarean section	24.4 (38)	20.5 (32)	26.8 (41)	16.7 (26)
Anaemia	14.7 (23)	20.5 (32)	21.2 (33)	16.7 (26)
Diabetes	14.7 (23)	20.5 (32)	23.7 (37)	14.7 (23)
Other medical disorders	14.1 (22)	18.6 (29)	20.2 (32)	12.8 (20)
Grand multiparity	19.2 (30)	21.8 (34)	21.8 (34)	11.5 (18)
Obesity	3.2 (5)	3.2 (5)	7.7 (12)	8.3 (13)
Hypertension	4.5 (7)	1.9 (3)	6.5 (10)	2.6 (4)
Preterm labour	1.3 (2)	1.9 (3)	2.6 (4)	2.6 (4)
Premature rupture of membranes	1.9 (3)	1.3 (2)	1.9 (3)	0.6 (1)
Prolonged obstructed labour	0.6 (1)	1.3 (2)	1.3 (2)	0.6 (1)
Other maternal conditions	3.8 (6)	2.6 (4)	14.1 (22)	0.6 (1)
Prolonged pregnancy ( $\geq 42$ weeks of gestation)	0.6 (1)	-	-	-
Pelvic abnormality	0.6 (1)	0.6 (1)	1.9 (3)	-
<b>Foetal conditions</b>	<b>14.1 (22)</b>	<b>17.9 (28)</b>	<b>18.6 (29)</b>	<b>12.2 (19)</b>
Multiple gestation	3.8 (6)	3.8 (6)	4.5 (7)	3.2 (5)
Polyhydramnios	2.6 (4)	2.6 (4)	2.6 (4)	1.9(3)
Abnormal presentation of foetus	2.6 (4)	3.8 (6)	2.6 (4)	0.6 (1)
Foetal abnormality	1.9 (3)	1.9 (3)	1.9 (3)	0.6 (1)
Oligohydramnios	1.9 (3)	2.6 (4)	1.9 (3)	-
Others	5.1 (8)	6.4 (10)	12 (7.7)	7.1 (11)
<b>Interventions</b>	<b>13.5 (21)</b>	<b>7.7 (12)</b>	<b>16.0 (25)</b>	<b>15.4 (24)</b>
Complications of anaesthesia	1.9(3)	1.9 (3)	1.9 (3)	2.6 (4)
Failed trial of labour	1.3 (2)	0.6 (1)	2.6 (4)	1.3 (2)
Failed vacuum extraction/forceps	1.3 (2)	0.6 (1)	0.6 (1)	-
Failed induction of labour	0.6 (1)	-	0.6 (1)	1.3 (2)
Other interventions	10.3 (16)	5.1 (8)	10.9 (17)	10.9 (17)

## 6.6. Chapter summary

This chapter presented the underlying causes of and conditions contributing to MNM as assigned by reviewers at the four levels of review: hospital, regional, national, and international. Across all levels of review, the group of hypertensive disorders of pregnancy was the leading cause of MNM, with more than 40% of the MNM events, followed by obstetric haemorrhage with more than 20%, and non-obstetric complications, which accounted for about 10% of the MNM events.

Severe pre-eclampsia, eclampsia, SCD disease, and morbidly adherent placenta were the most common leading specific causes of MNM. Only a slight variation was observed in this order across the different review panels.

Almost perfect level of agreement was observed between hospital and regional reviewers as well as between hospital and national reviewers in assigning ICD-MM group of underlying cause of MNM, with k-value of 0.9. Also, there was a substantial agreement between the regional and national reviewers with k- value of 0.8. There was a substantial agreement between individual groups of country reviewers and the International Expert Panel with k- value of 0.8.

Contributory conditions were identified in more than 50% of all MNM events, with the highest identified percentage recorded by the national reviewers (81%), and the lowest by the international reviewers (65%).

Maternal conditions were the most common recorded contributing condition by all review panels, and contributed to more than 50% of the MNM events. Previous caesarean section was the single leading contributory condition and was recorded in more than 20% of MNM events by in-country reviewers (hospital, regional, national), and in 17% (n = 26) by the international reviewers. Medical disorders including anaemia, diabetes, and the group of other medical disorders were the second most common conditions assigned by regional, national, and international reviewers, followed by grand multiparty.

Conditions related to the foetus and those related to interventions contributed to less than 20% of the events as reported by all reviewers. Each specific cause within these categories contributed to less than 5.0% of the events.

## 7. Quality of Care and Associated Factors in MNM

This chapter focuses on the assessment of QoC provided to women with MNM and the factors associated with MNM events. It addresses the following research questions:

- What is the standard of care the women with MNM received?
- What are the factors associated with MNM events?

The chapter is divided into five sections. The first section presents the assessment of QoC as agreed by the reviewers at the four levels of review; hospital, regional, national and international. A comparison between findings of the different groups of reviewers with level of agreement is described in section two. Section three presents a description of the associated factors reported by the reviewers at each level, while in section four, a comparison of these factors by level of review is presented

### 7.1. Assessment of Quality of Care

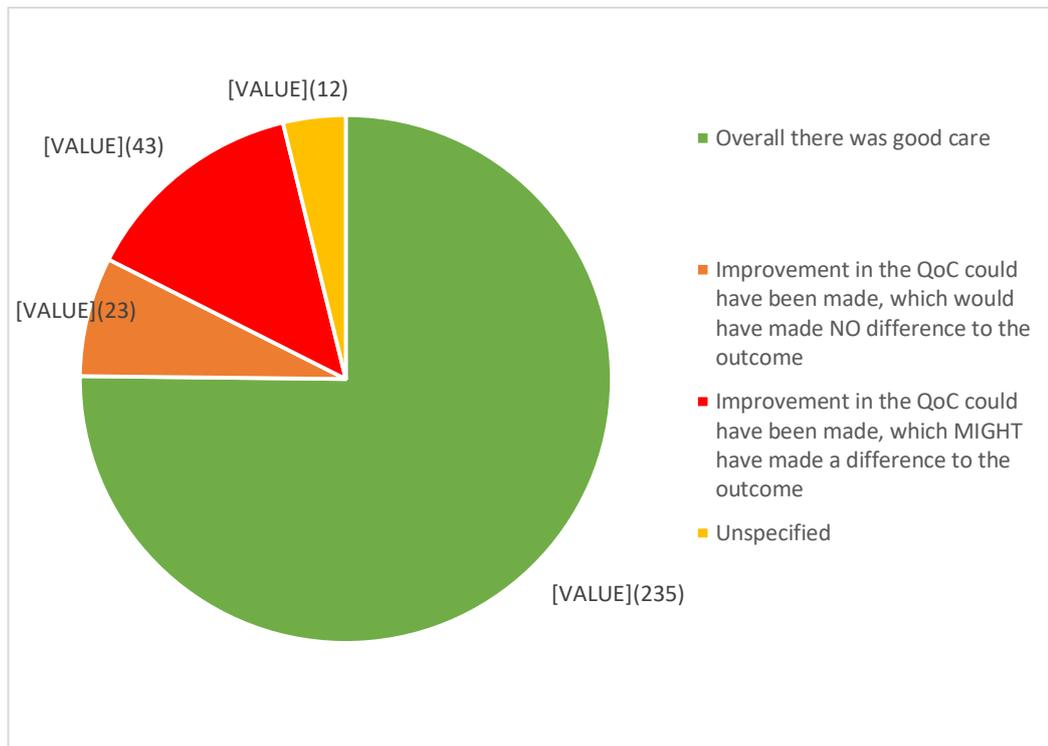
The classification of QoC was adopted from the UK Confidential Enquiry into Maternal Deaths, as explained in chapter 3. Briefly, there are three categories:

- Overall there was good care
- Improvement in the QoC could have been made, which would have made no difference to the outcome (QoC improvement possible, but with no difference to the outcome).
- Improvement in the QoC could have been made, which might have made a difference to the outcome (QoC improvement possible, with possible difference to outcome).

This section first presents the overall assessment of QoC for women with MNM events by reviewers at each level of review, then the analysis of QoC by underlying causes of MNM is described.

### 7.1.1. Assessment of quality of care by reviewers at the hospital level

The reviewers at the hospital level found that in 75.1% (n = 235) of 313 MNM events, the QoC provided was good. Areas for improvement of provided care were identified in 21.0% (n = 66) of MNM events. Such improvements might have made a difference to the outcome in 13.7% (n = 43) of cases (**Figure 7.1**).



*Figure 7.1: Assessment of quality of care by assessors at the hospital level*

The highest proportion of events where improvement in care might have made a difference to the outcome was within the group of pregnancy with abortive outcome (23.5%, n = 4), followed by the group of hypertensive disorders of pregnancy (17.1%, n = 22), then obstetric haemorrhage (15.3%, n = 11) (**Table 7.1**).

Table 7.1: Assessment of QoC and underlying causes by reviewers at the hospital level

ICD-MM group of underlying causes	Classification of Care % (n) of MNM events within the groups of underlying causes			
	Overall good care	QoC improvement possible, but with no difference to the outcome	QoC improvement possible, with possible difference to outcome	Unspecified
Pregnancy with abortive outcome (n = 17)	64.7 (11)	11.8 (2)	23.5 (4)	-
Hypertensive disorders of pregnancy (n = 129)	73.6 (95)	5.4 (7)	17.1 (22)	3.9 (5)
Obstetric haemorrhage (n = 72)	75.0 (54)	6.9 (5)	15.3 (11)	2.8 (2)
Pregnancy-related infections (n = 8)	62.5 (5)	12.5 (1)	12.5 (1)	12.5 (1)
Other obstetric complications (n = 20)	85.0 (17)	5.0 (1)	5.0 (1)	5.0 (1)
Unanticipated complications of management (n = 9)	44.4 (4)	33.3 (3)	11.1 (1)	11.1 (1)
Non-obstetric complications (n = 53)	83.0 (44)	7.5 (4)	5.7 (3)	3.8 (2)
Unspecified	100.0 (5)	-	-	-

### 7.1.2. Assessment of QoC by the Regional Maternal Mortality Committee

Out of the 290 MNM cases reviewed by the Regional Maternal Mortality Committee, which concluded that the care was good in 68.3% (n = 198), and in 30.7% (n = 94) improvements in the QoC could have been made. In 21.7% (n = 68), such improvement could have made a difference to the outcome of women with the MNM events (Figure 7.2).

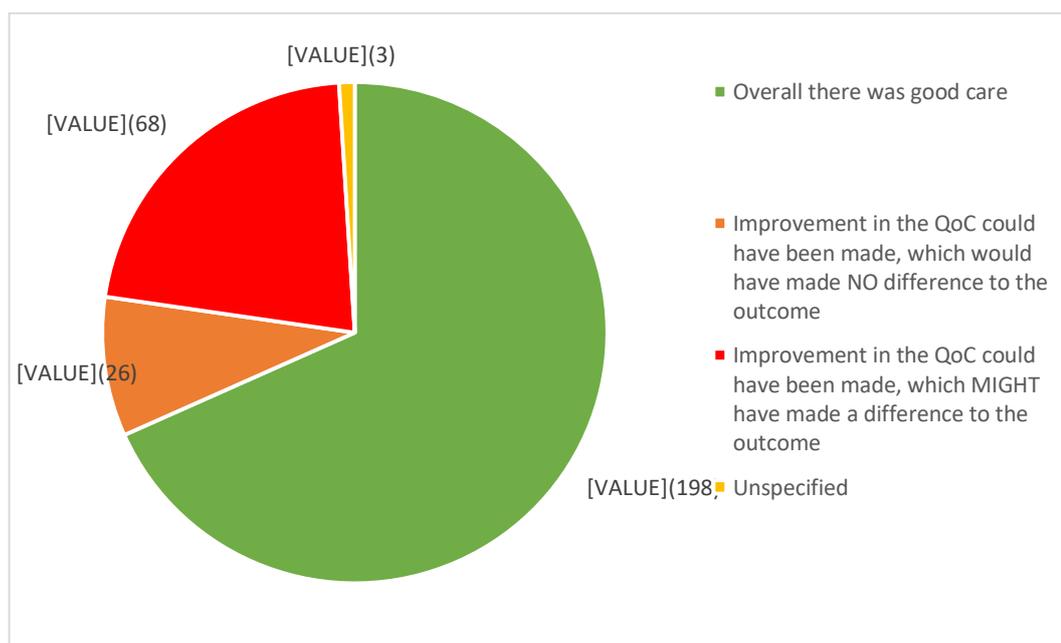


Figure 7.2: Assessment of QoC at the regional level

Further analysis of the assigned classification of care revealed that the highest percentage of events with improvement in the QoC that might have made a difference to the outcome was within the group of pregnancy-related infection, with 71.4% (n = 5) of the seven events. This was identified in about a quarter (24.3%, n = 18) of obstetric haemorrhage events, and in about one-fifth of hypertensive disorders events (n = 27, 21.6%) (**Table 7.2**).

*Table 7.2: Assessment of QoC and underlying causes of MNM by reviewers at the regional level*

ICD-MM group of underlying causes	Classification of Care			
	% (n) of MNM events within the groups of underlying causes			
	Overall good care	QoC improvement possible, but with no difference to the outcome	QoC improvement possible, with possible difference to outcome	Unspecified
Pregnancy with abortive outcome (n = 11)	81.8 (9)	9.1 (1)	9.1 (1)	-
Hypertensive disorders of pregnancy (n = 125)	68.0 (85)	9.6 (12)	21.6(27)	0.8(1)
Obstetric haemorrhage (n = 74)	63.5 (47)	10.8 (8)	24.3 (18)	1.4(1)
Pregnancy-related infections (n = 7)	28.6 (2)	-	71.4 (5)	-
Other obstetric complications (n = 15)	73.3 (11)	-	26.7 (4)	-
Unanticipated complications of management (n = 6)	100 (6)	-	-	-
Non-obstetric complications (n = 51)	72.5 (37)	9.8 (5)	15.7 (8)	2.0 (1)

### 7.1.3. Assessment of QoC by the National Maternal Mortality Committee

Out of the 156 MNM events reviewed by the National Maternal Mortality Committee, the provided care was deemed good in half (50.6%, n = 79) of the MNM events, and in over a third (34.6%, n = 54) an improvement in the QoC provided could have made a difference to the outcome of women with these severe events (**Figure 7.3**).

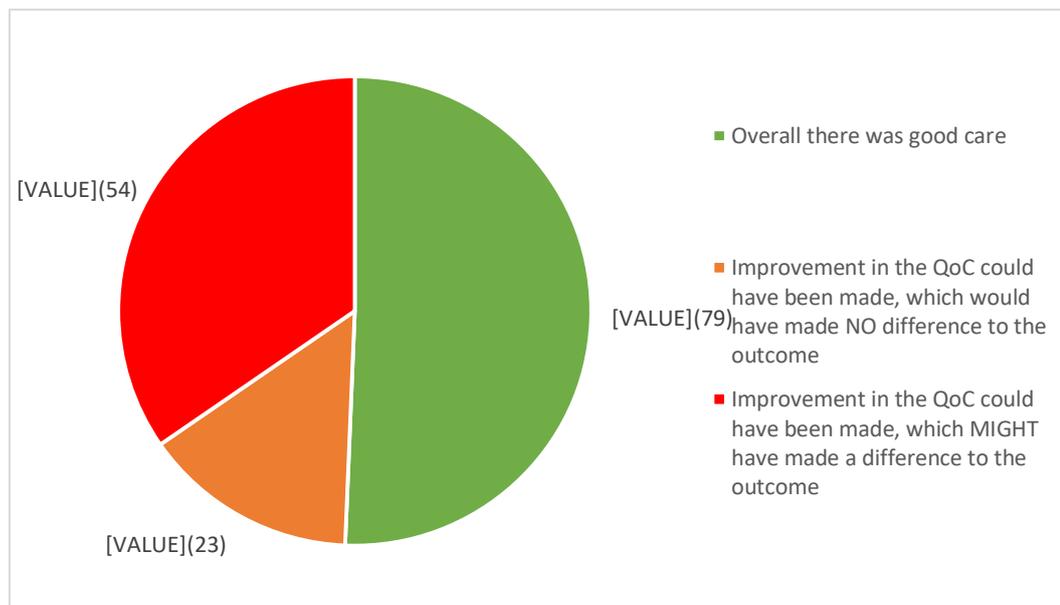


Figure 7.3: Assessment of QoC by reviewers at the national level

The highest proportion of MNM events in which improvements of care might have made a difference to the outcome were within the group of hypertensive disorders, with 43.1% (n = 28) of the 65 events, followed by obstetric haemorrhage and non-obstetric complications (Table 7.3).

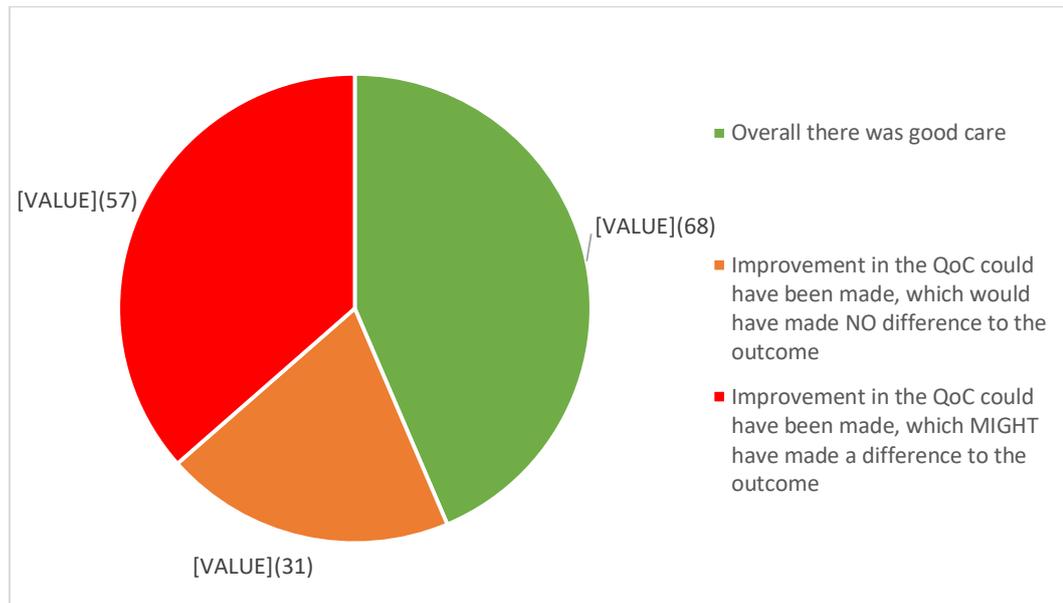
Table 7.3: Assessment of QoC and underlying causes of MNM by reviewers at the national level

ICD-MM group of underlying causes	Classification of Care			
	% (n) of MNM events within the groups of underlying causes			
	Overall good care	QoC improvement possible, but with no difference to the outcome	QoC improvement possible, with possible difference to outcome	Unspecified
Pregnancy with abortive outcome (n = 4)	50.0 (2)	50.0 (2)	-	-
Hypertensive disorders of pregnancy (n = 65)	44.6 (29)	12.3 (8)	43.1 (28)	-
Obstetric haemorrhage (n = 43)	44.2 (19)	16.3 (7)	39.9 (17)	-
Pregnancy-related infections (n = 2)	100.0 (2)	-	-	-
Other obstetric complications (n = 7)	71.4 (5)	14.3 (1)	14.3 (1)	-
Unanticipated complications of management (n = 6)	66.7 (4)	16.7 (1)	16.7 (1)	-
Non-obstetric complications (n = 29)	62.1 (18)	13.8 (4)	24.1 (7)	-

#### 7.1.4. Assessment of QoC by the International Expert Panel

Among the 156 MNM events assessed by the expert panel members, in 43.3% of cases (n = 68) the panel found that the care provided to the women was good, but in

another 36.5% (n = 57), the improvements in care might have made a difference to the outcomes of these women (**Figure 7.4**).



*Figure 7.4: Assessment of QoC by the International Expert Panel*

When examining the assessment of QoC for the groups of specific causes, a variation was observed between the different groups. The panel identified areas for improvement in the care provided in all five MNM events with unanticipated complications of management (100%). In 80% (n = 4) of these events, such improvement might have a difference in the outcome. In the rest of the groups of the underlying cause (except for the group of pregnancy-related infections), an improvement in care were identified in nearly 50.0% or more of the MNM events. In around one-third of these events it was considered that such improvements might have made a difference to the outcome (**Table 7.4**).

*Table 7.4: Underlying causes of MNM and assessment of QoC by the International Expert Panel*

ICD-MM group of underlying causes	Classification of care n (%) of MNM events within the groups of underlying causes			
	Overall good care	QoC improvement possible, but with no difference to the outcome	QoC improvement possible, with possible difference to outcome	Unspecified
Pregnancy with abortive outcome (n = 4)	50.0(2)	50.0(2)	-	-
Hypertensive disorders of pregnancy (n = 65)	46.2 (30)	20.0 (13)	33.8 (22)	-
Obstetric haemorrhage (n = 40)	45.0 (18)	17.5 (7)	37.5 (15)	-
Pregnancy-related infections (n = 1)	-	-	100.0(1)	-
Other obstetric complications (n = 13)	30.8 (4)	23.1 (3)	46.2 (6)	-
Unanticipated complications of management (n = 5)	-	20.0 (1)	80.0 (4)	-
Non-obstetric complications (n = 28)	50.0 (14)	17.9 (5)	32.1 (9)	-

## 7.2. Comparison of assessment of QoC by reviewers at the four different levels of review

The 156 MNM events reviewed at the four different levels of review were selected to compare the assessments of QoC made by the different reviewers. There was an increase in the proportion of MNM events for which it was considered improvements in the QoC could have been made with an increase in the level of review (**Table 7.5**). The proportion of events where improvement in the QoC might have made a difference to the outcome identified by the international panel (36.5%, n = 57) and national reviewers (34.4%, n = 54) was higher than that at the hospital (10.9%, n = 17) and regional (19.9%, n = 31) review levels.

Table 7.5: Comparison of assessment of the quality of care by different reviewer panels

Classification of care	Hospital reviewers (n = 156)	Regional reviewers (n = 156)	National reviewers (n = 156)	International panel (n = 156)
	% (n)			
Overall good care	74.4 (116)	67.9 (106)	50.6 (79)	43.6(68)
QoC improvement possible, but with no difference to the outcome	10.3 (16)	11.2 (11)	14.7 (23)	19.9 (31)
QoC improvement possible, with possible difference to outcome	10.9 (17)	19.9 (31)	34.4 (54)	36.5 (57)
Unspecified	4.5 (7)	0.6(1)	-	-

Level of agreement in assessing the quality of care was measured between different reviewers by calculating Cohen's kappa coefficient ( $\kappa$ ). The 148 MNM events with the assigned classification of care by all groups of reviewers were selected to calculate  $\kappa$  value. As shown in **Table 7.6**, there was substantial agreement in the assessment of care between hospital and regional reviewers, which was statistically highly significant ( $\kappa = 0.7$ ,  $p$ -value  $<0.001$ ). They had a slight agreement with the national reviewers ( $\kappa = 0.1$ ,  $p = 0.027$ ), and poor agreement with the International Expert Panel, but this was not statistically significant. The regional reviewers had a slight statistically significant agreement with the national reviewers ( $\kappa = 0.1$ ,  $p = 0.001$ ), but their agreement with the International Expert Panel was not statistically significant ( $\kappa = 0.1$ ,  $p = 0.787$ ). There was a slight agreement between the national reviewers and the International Expert Panel, which was statistically significant ( $\kappa = 0.1$ ,  $p = 0.008$ ).

Table 7.6: Level of agreement between different panels in the assessment of QoC for MNM cases

Level of review	$\kappa$ -value (95% CI)	P-value
Hospital vs regional	0.7 (0.36;0.61)	$<0.001$
Hospital vs national	0.1 (0.0;0.17)	0.027
Hospital vs international	0.0 (0.0;0.61)	0.787
Regional vs national	0.1 (0.17;0.31)	0.001
Regional vs international	0.1 (0.08;0.12)	0.826
National vs international	0.1 (0.03;0.26)	0.008

A further analysis was conducted to explore the difference between the assessment of the national and the international panel, which revealed that they agreed on assigning QoC for 47.0% (70/148) of MNM events. In 14% (20/148) of the MNM

events, the national reviewers felt the woman received good care, while the international panel identified areas for improvement, which might have made a difference to the outcome. On the other hand, in 10.0% (15/148), the national reviewers found areas for improvement in the care provided, which might have made a difference to the outcome, but the expert panel disagreed and concluded that the woman received good care (**Table 7.7**).

*Table 7.7: Comparing the assessment of the quality of care between the national reviewers and International Expert Panel*

		International Expert Panel			Total MNM events
		1	2	3	
National Review Committee	1	<b>25.6% (38)</b>	9.5% (14)	13.5% (20)	48.6% (72)
	2	8.1% (12)	<b>3.4% (5)</b>	3.4% (5)	14.9% (22)
	3	10.1% (15)	8.1% (12)	<b>18.2% (27)</b>	36.5% (54)
Total		43.9% (65)	20.9% (31)	35.1% (52)	148

1 = Good care

2 = QoC improvement possible, but with no difference to the outcome

3 = QoC improvement possible, with possible difference to outcome

Examining the underlying causes of these events showed that disagreement between the two committees was mainly in the MNM events with hypertensive disorders of pregnancy and unanticipated complications of management. They disagreed on the assessment of care for 26.2% (17/65) of hypertensive disorders of pregnancy, and half of events with unanticipated complications of management (**Annex 21**).

A similar analysis was conducted to explore the difference between the assessment of the hospital and the international panel, which revealed that they agreed on assigning QoC for 41.2% (61/148) of MNM events and disagreed on 58.8% (87/148). In 25.0% (37/148) of the MNM events, the hospital reviewers felt the woman received good care, while the international panel identified areas for improvement, which might have made a difference to the outcome (**Table 7.8**).

*Table 7.8: Comparing the assessment of the quality of care between the hospital reviewers and International Expert Panel*

		International Expert Panel			Total MNM events
		1	2	3	
Hospital Reviewers	1	<b>35.8 % (53)</b>	16.9% (25)	25.0% (37)	77.7% (115)
	2	4.7% (7)	<b>0.7% (1)</b>	5.4% (8)	10.8% (16)
	3	3.4% (5)	3.4% (5)	<b>4.7% (7)</b>	11.5% (17)
Total		43.9 (65)	20.9% (31)	35.1% (52)	148

Further analysis revealed they disagreed on assigning QoC for all the MNM events with pregnancy with abortive outcome (4/4) as well as those under group of other obstetric complications (13/13). They had disagreement on assigning QoC for 80% (4/5) of MNM events with un-anticipated complications of management, 52% (20/38) with those with obstetric haemorrhage and 50% for each group of events with hypertensive disorders of pregnancy (35/63) and group of non-obstetric complications (13/25).

### **7.3. Factors associated with MNM**

Factors associated with MNM are non-medical factors that considered to have contribute to the occurrence of an MNM. As presented in the methodology chapter, these can be divided into three categories:

1. The organisation of care: This category examined the elements related to the organisation of care and the wider healthcare system.
2. The healthcare team (HCT): This category focuses mostly on the clinical aspects of the care provided by the healthcare team who attended to the woman with MNM.
3. The woman herself: This pertains to issues related to the woman and her family that affected the patient health outcomes.

This section presents the overall factors recorded by reviewers at the four levels of review and describes the identified factors within each group of underlying causes of MNM will be described.

#### **7.3.1. Associated factors identified by reviewers at the hospital level**

The assessors identified associated factors in 50.8% (n = 159) of MNM events. Collectively, factors related to the healthcare team providing the care were the most commonly identified factors (**Table 7.9**), attributed in nearly one-third of events. Inappropriate management of cases, delay in diagnosis of the severity of the condition, and delay in referring the woman to a higher level of care were the most frequently recorded factors within this category, with 8.6% (n = 27), 8.3% (n = 26), and 7.3% (n = 23), respectively.

Factors related to the organisation of care were the second most commonly identified factors. Staff related factors were the most commonly attributed factors (10.2%, n = 32). Inadequate number of staff and poor access to senior staff were attributed to 5.1 (n=16) and 4.2 (n=13) of MNM events. Non-availability of policy/

guidelines and outdated guidelines contributed to 4.8% (n = 15) all MNM events. Non-availability of blood/ blood products and non-availability of equipment contributed to 4.5% (n=14) and 4.2 (n=13), respectively. The common recorded non-available equipment were Bakri Balloon and cell saver for management of obstetric haemorrhage at regional hospitals as well as equipment for emergency operating theatre at district hospitals.

Factors related to the woman herself were associated with 18.5% (n = 58) of MNN events. Non-adherence to prescribed treatment was identified as a contributing factor with 8.0% (n = 25). The rest of the factors were identified in less than 5.0% of events.

Table 7.9: Factors associated with MNM identified by assessors at the hospital level

Factors identified	% (n) of the 313 MNM events <sup>6</sup>
<b>Related to the organisation of care</b>	<b>18.8 (59)</b>
<b>Related to staff</b>	<b>10.2 (32)</b>
Inadequate number of staff	5.1 (16)
Poor access to senior staff	4.2 (13)
Other	1.3 (4)
unspecified	0.3 (1)
<b>Related to policy and guidelines</b>	<b>4.8 (15)</b>
Non-availability of guidelines	1.6 (5)
Outdated guidelines	1.3 (4)
Non-availability of policy	1 (3)
<b>Related to referral</b>	<b>1.9 (6)</b>
Transportation problem	1.0 (3)
Non- availability of bed in a higher care facility	0.3 (1)
<b>Medication</b>	<b>2.6 (8)</b>
Non-availability of medication	0.6 (2)
Unspecified	2.0 (6)
<b>Equipment</b>	<b>4.8 (15)</b>
Non-availability of equipment	4.2 (13)
Un-specified	0.3 (1)
<b>Non-availability of blood/blood products</b>	<b>4.5 (14)</b>
<b>Long distance from a healthcare facility</b>	<b>0.3 (1)</b>
<b>Other</b>	<b>1.3 (4)</b>
<b>Related to the healthcare team</b>	<b>32.6 (102)</b>
Inappropriate management	8.6 (27)
Delay in referral to a higher care facility	8.3 (26)
Delay in diagnosis of the condition	7.3 (23)
Poor quality of care during transferring the woman to a higher healthcare facility	4.5 (14)
Failure to recognise the seriousness of the condition	3.8 (12)
Inappropriate condition of transferring woman to a higher care facility	3.8 (12)
Incomplete or delayed assessment of condition	3.2 (10)
Delay in emergency response	2.2 (7)
Inappropriate monitoring	2.2 (7)
Communication failure between the healthcare team	0.6 (2)
Failure to involve other specialities	0.6 (2)
Others	1.9 (6)
<b>Related to woman herself</b>	<b>18.5 (58)</b>
Non-adherence to treatment	8.0 (25)
Delay in seeking care	2.9 (9)
Declined medication or procedure	2.6 (8)
No ANC care	1.6 (5)
Late booking for ANC care	1.3 (4)
Other	3.2 (10)

**Figure 7.5** illustrates the analysis of these factors for different ICD-MM groups of underlying causes of MNM. Variations were observed, for example factors related to the healthcare team were the leading factors in MNM events with hypertensive

<sup>6</sup> Each MNM case can have more than one associated factor. Thus, the total cannot be added up to 100%

disorders of pregnancy, pregnancy-related infections, other obstetric complications and non-obstetric complications. Factors related to the organisation of care were leading in cases of pregnancy with abortive outcome, and unanticipated complications of management. Factors related to the woman (i.e. patient-related factors) were highest in the group of pregnancy with abortive outcome and non-obstetric complications.

**Annex 22** presents the three leading specific factors for each ICD- group. Delay in emergency response was recorded in all MNM cases (n=17) with pregnancy with abortive outcome, while delay in diagnosis of the condition and management failure contributed to 93.8% (n=15), and 82.4% (n=14), respectively. Delay in emergency response (93.8%, n=121), failure in monitoring (93.8%, n=121) and inappropriate management (90.7%, n=117) were the leading factors in cases with hypertensive disorders. Staff related factors (18.1%, n=13) and delay in diagnosis of the condition (11.1%, n=10) were the highest recorded factors among cases with obstetric haemorrhage. Failure to recognise the seriousness of the condition, inappropriate management, woman delay in seeking care and non-adherent to the prescribed medications were the leading factors with pregnancy related infection, other obstetric complications and non-obstetric complications.

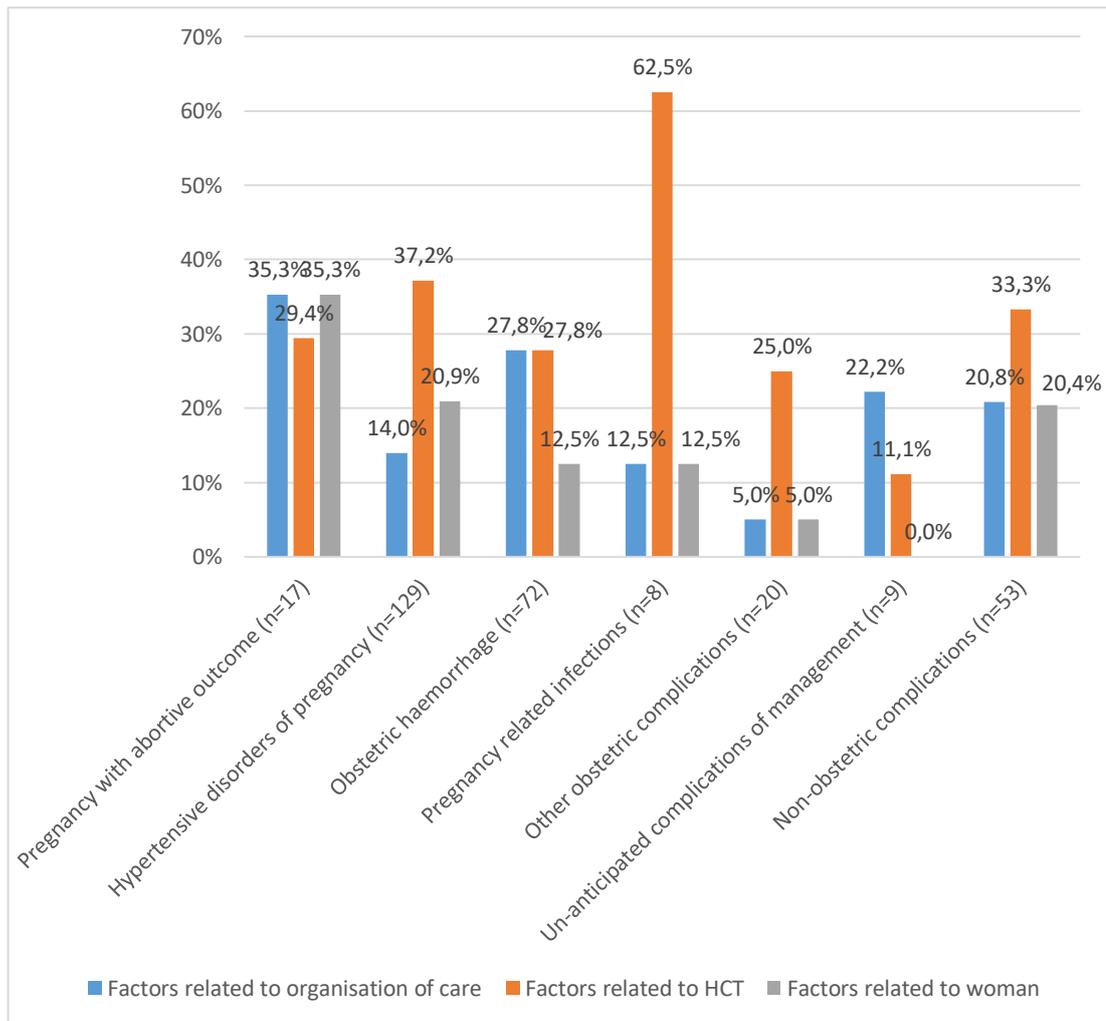


Figure 7.5: Factors associated for causes of MNM as assessed by hospital level review panel

### 7.3.2. Associated factors identified by the Regional Maternal Mortality Committee

Among the 290 MNM events, the Regional Maternal Mortality Committee identified associated factors in 54.8% (n = 159) of all MNM events. Factors related to the woman herself (32.1%, n = 93) were the most common, followed by those related to the healthcare team (28.3%, n = 82) and the organisation of care (17.2%, n = 50) (Table 7.10).

Delay in seeking care was the most commonly identified factors in 12.1% (35) of the 290 MNM events. Non-adherence of a woman with prescribed treatment contributed to 9.3% (n = 27) of MNM events, and refusal to take medication or undergo a procedure contributed to 5.2% (n = 15).

Failure of the attending healthcare team to recognise the seriousness of the conditions was identified factors in 11.0% (n = 32). Inappropriate management, delay in diagnosis and delay in referral to a higher care facility contributed to 7.2% (n = 21), 6.6% (n = 19) and 5.5% (16) respectively.

Staff factors were the most common identified factor among the category of organisation of care, with 5.5% (n = 16) of MNM events. Factors related to policy and guidelines (non-availability or outdated) were recorded in 3.8% (11). These were related to management of i) invasive placenta (8/11), ii) SCD (1/11), iii) hypertensive disorders of pregnancy (1/11) and iv) pregnancy with abortive outcome (1/11). Non-availability of equipment contributed to 3.8% (11) of MNM cases. The committee recorded a shortage of Bakri Balloon, non-availability of cell saver machine and machine for exchange transfusion for management of SCD at regional hospitals. Non-availability of blood/blood product and non-availability of medication associated with 2.4% (7) and 1.7% (5) of the 290 MNM events, respectively. In the latter, the commonest identified non-available medication was Magnesium Sulphate (4/5) at primary healthcare facilities for management of severe pre-eclampsia/ eclampsia. Long distance from healthcare facility was attributed as a factor in 1.4% (4). In these events, the accessible healthcare facility not equipped to manage the severe complication and women had to be referred to another facility. These events were related to hypertensive disorders of pregnancy (eclampsia), obstetric haemorrhage (abruptio placenta and postpartum haemorrhage) and other obstetric complications (peripartum cardiomyopathy).

Table 7.10: Factors associated with MNM identified by reviewers at the regional level

Factors identified	% (n) of the 290 MNM <sup>7</sup> events
<b>Related to the organisation of care</b>	17.9 (52)
<b>Related to staff</b>	<b>5.5 (16)</b>
Inadequate number of staff	3.1 (9)
Poor access to senior staff	2.4 (7)
<b>Related to policy and guidelines</b>	<b>3.8 (11)</b>
Non-availability of guidelines	1.4 (4)
Non-availability of policy	1.0 (3)
Outdated guidelines	0.7 (2)
<b>Related to equipment (Non-availability of equipment)</b>	3.8 (11)
<b>Related to referral</b>	2.1 (6)
Transportation problem	1.4 (4)
Non-availability of bed in a higher care facility	0.3 (1)
Unspecified factors related to referral	0.3 (1)
<b>Related to blood</b>	2.8 (8)
Non-availability of blood/blood product	2.4 (7)
Unspecified factor related to blood	0.3 (1)
<b>Related to medication (Non-availability of medication)</b>	1.7 (5)
<b>Related to laboratory</b>	1.0 (3)
Delay access to test results	0.7 (2)
Non-availability of test	0.3 (1)
<b>Long distance from a healthcare facility</b>	1.4 (4)
<b>Other</b>	1.7 (5)
<b>Related to healthcare team</b>	<b>28.3 (82)</b>
<b>Failure to recognise the seriousness of the condition</b>	11.0 (32)
<b>Inappropriate management</b>	7.2 (21)
<b>Delay in diagnosis of the condition</b>	6.6 (19)
<b>Delay in referral to a higher care facility</b>	5.5 (16)
<b>Failure to assess the severity of the condition</b>	3.8 (11)
<b>Incomplete or delayed assessment of condition</b>	3.4 (10)
<b>Delay in emergency response</b>	2.4 (7)
<b>Communication failure between the healthcare team</b>	1.4 (4)
<b>Failure to involve other specialities</b>	0.3 (1)
<b>Others</b>	5.5 (16)
<b>Related to woman herself</b>	<b>32.1 (93)</b>
<b>Delay in seeking care</b>	12.1 (35)
<b>Non-adherence to treatment</b>	9.3 (27)
<b>Late booking for ANC care</b>	5.9 (17)
<b>Declined medication or procedure</b>	5.2 (15)
<b>No ANC care</b>	4.5 (13)
<b>Long distance from a healthcare facility</b>	1.4 (4)
<b>Other</b>	5.9(17)

<sup>7</sup> Each MNM case can has more than one associated factor.

**Figure 7.6** presents the distribution of identified associated factors within ICD-groups of underlying causes of MNM events. The committee identified factors associated with 50% or more of MNM events within groups of underlying causes of MNM except for pregnancy-related infections (28.6%, n = 2) and those with unanticipated complications of management (16.7%, n = 1). The highest proportion of healthcare team related factors was within the group of obstetric haemorrhage (33.8%, n = 25) and other obstetric complications (33.3%, n = 5). Obstetric haemorrhage also had the highest recorded factors related to the organisation of care (29.7%, n = 22). Factors related to the woman were most frequently identified within the group of pregnancy with abortive outcome (54.5%, n = 6), non-obstetric complications (37.3%, n = 19) and hypertensive disorders of pregnancy (32.8%, n = 41). **Annex 23** presents the leading specific factors for each ICD-group of underlying cause.

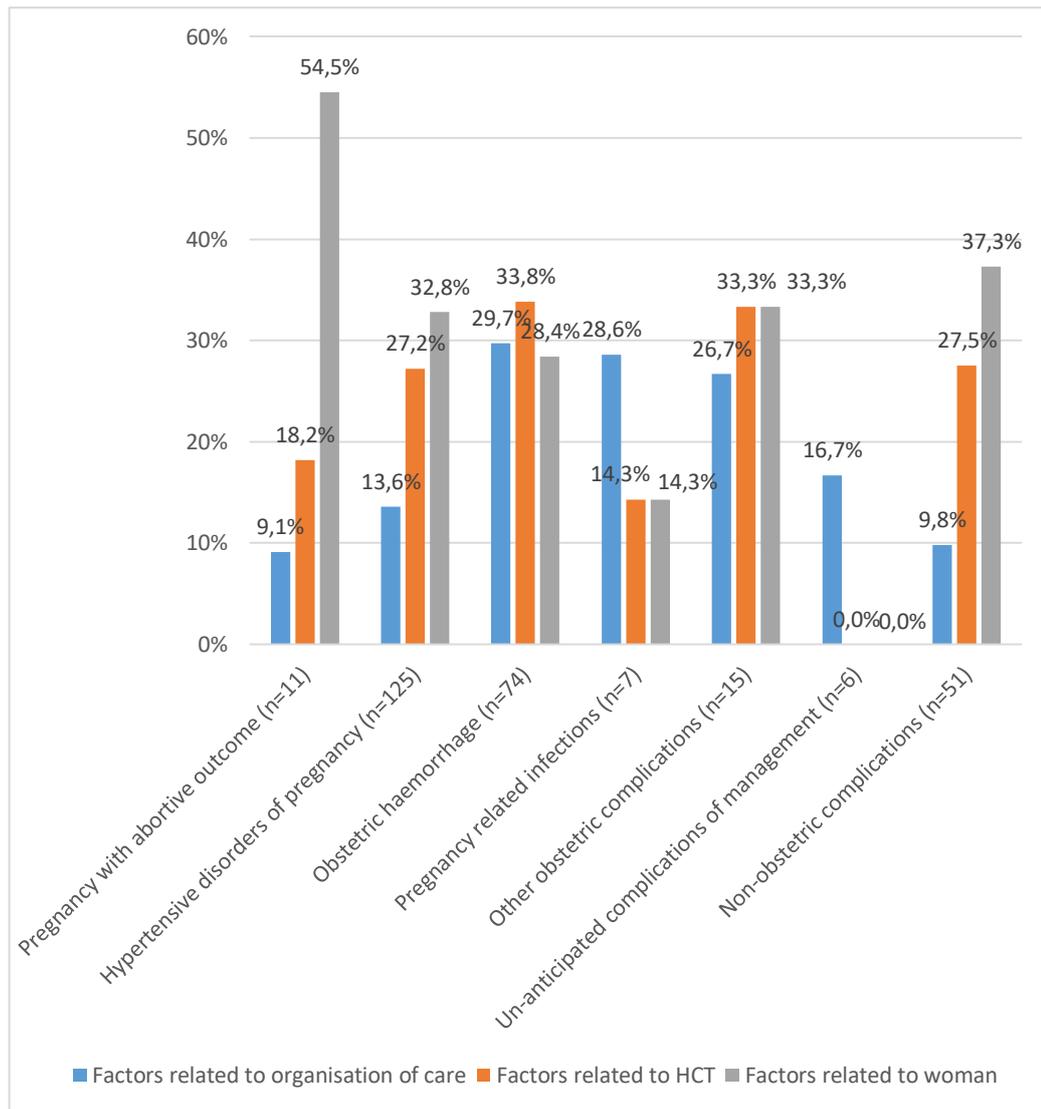


Figure 7.6: Associated factors and underlying causes of MNM by reviewers at the regional level

### 7.3.3. Associated factors identified by the National Maternal Mortality Committee

Among the 156 MNM events reviewed by the National Maternal Mortality Committee, the reviewers identified associated factors in 70.5% (n = 110) of MNM events. Factors related to the treating healthcare team were the most commonly identified factors (44.2%, n = 69). Failure of the attending healthcare providers to recognise the seriousness of a woman's condition was the most frequently identified factor and was associated with slightly more than one-quarter of all MNM events (25.6%, n = 40). Inappropriate management of the case, failure to assess the

severity of the condition, and delay in diagnosis of the severe condition were associated with 16.7% (n = 26), 11.5% (n = 18), and 10.3% (n = 16) of MNM events.

Factors related to the woman herself were the second most commonly identified factors, with 32.1% (n = 50). Non-adherence of a woman to prescribed treatment was associated with 10.9% (n = 17) of the 156 MNM events, while delay in seeking medical care and late booking for ANC were identified in 9.6% (n = 15) and 8.3% (n = 13), respectively.

Factors related to the organisation of care were identified in 26.9% (n = 42) of the 156 MNM events. Staff factors and those related to policy and guidelines were the most commonly identified factors in this group, with 9.6% (n = 24) each. Inadequate number of staff contributed to 5.1% (n=8) and poor access to senior staff to 3.8% (6). The non-available /outdated guidelines were those related to management of invasive placenta, SCD and hypertensive disorders of pregnancy. Failure in the referral system was the second most frequent identified factor, with 5.1% (n = 8) (**Table 7.11**). Non-availability of equipment and non-availability of blood/blood products contributed to 3.2% (n=5) each. The non-available equipment were Bakri Balloon, machine for cell saver and machine for exchange transfusion, which are similar to the recorded equipment by the reviewers at hospital and regional levels.

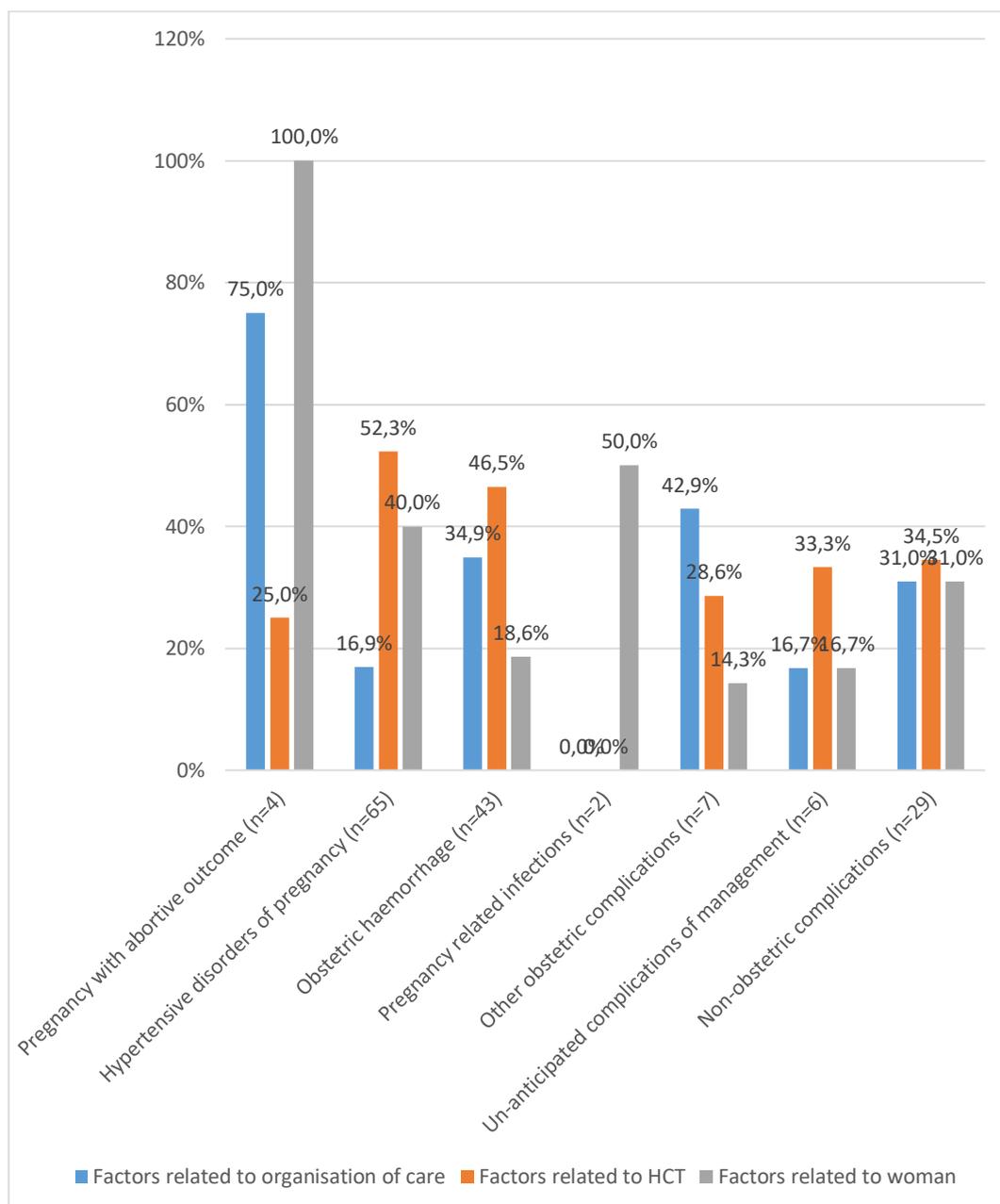
Table 7.11: Factors associated with MNM identified by reviewers at the national level

Factors identified	% (n) of 156 MNM events <sup>8</sup>
<b>Related to the organisation of care</b>	<b>43 (27.6)</b>
<b>Related to policy and guidelines</b>	<b>9.6 (15)</b>
Non-availability of policy	3.2 (5)
Non-availability of guidelines	2.6 (4)
Outdated guidelines	1.9 (3)
Unspecified factors related to policy and guidelines	2.7 (4)
<b>Related to staff</b>	<b>9.6 (15)</b>
Inadequate number of staff	5.1 (8)
Poor access to senior staff	3.8 (6)
Unspecified factors related to staff	1.9 (3)
<b>Related to referral</b>	<b>5.1 (8)</b>
Transportation problem	1.9 (3)
Non-availability of bed in higher care facility	1.9 (3)
Unspecified factors related to referral	1.3 (2)
<b>Related to equipment</b>	<b>3.8 (6)</b>
Non-availability of equipment	3.2 (5)
Non-functioning equipment	0.6 (1)
<b>Related to blood/blood product</b>	<b>3.2 (5)</b>
Non-availability of blood/ blood products	2.6 (4)
Unspecified factors related to blood/ blood products	0.6 (1)
<b>Related to laboratory</b>	<b>1.9 (3)</b>
Inaccurate laboratory test results	1.3 (2)
Non-availability of laboratory test	0.6 (1)
<b>Related to medication</b>	<b>1.3 (2)</b>
Non-availability of medication	0.6 (1)
Unspecified factors related to medication	0.6 (1)
<b>Long distance from a healthcare facility</b>	<b>1.9 (3)</b>
<b>Other</b>	<b>5.8 (9)</b>
<b>Related to healthcare team</b>	<b>44.2 (69)</b>
<b>Failure to recognise the seriousness of the condition</b>	<b>25.6 (40)</b>
<b>Inappropriate management</b>	<b>16.7 (26)</b>
<b>Failure to assess the severity of the condition</b>	<b>11.5 (18)</b>
<b>Delay in diagnosis of the condition</b>	<b>10.3 (16)</b>
<b>Delay in referral to a higher care facility</b>	<b>9.6 (15)</b>
<b>Incomplete or delayed assessment of condition</b>	<b>8.3 (13)</b>
<b>Failure to involve other specialities</b>	<b>3.8 (6)</b>
<b>Delay in emergency response</b>	<b>3.2 (5)</b>
<b>Communication failure between the healthcare team</b>	<b>3.2 (5)</b>
<b>Others</b>	<b>10.3 (16)</b>
<b>Related to woman herself</b>	<b>31.4 (49)</b>
<b>Non-adherence to treatment</b>	<b>10.9 (17)</b>
<b>Delay in seeking care</b>	<b>9.6 (15)</b>
<b>Late booking for ANC care</b>	<b>8.3 (13)</b>
<b>No ANC care</b>	<b>7.1 (11)</b>
<b>Declined medication or procedure</b>	<b>4.5 (7)</b>
<b>Other</b>	<b>9.0 (14)</b>

The National Committee identified associated factors in 50% or more of MNM events in all groups of underlying causes. The highest number of healthcare related

<sup>8</sup> Each MNM case can have more than one associated factor.

factors were within the hypertensive disorders of pregnancy, obstetric haemorrhage, and non-obstetric complications, with 52.3% (n = 34), 46.5% (n = 20), and 34.5% (n = 10), respectively. Factors related to the organisation of care were the major contributors to MNM events due to other obstetric complications (42.9%, n = 3), and they also contributed to 75.0% of MNM events with pregnancy with an abortive outcome. In the latter group, factors related to the woman were the main factors identified in all four MNM events (**Figure 7.7**).



*Figure 7.7: Factors associated with MNM and underlying causes identified by reviewers at the national level*

**Annex 24** present the leading specific factors for each ICD-group of underlying cause. Failure to recognise the seriousness of the condition (33.8%, n=22) and inappropriate management (27.7%, n=18) were the leading factors associated with hypertensive disorders of pregnancy. The common identified themes were related to use of magnesium sulphate (initiation, dosage, and discontinuation) (n=6), inappropriate control of hypertension (n=6), use of diazepam in management of eclampsia (n=2),

Failure to recognise the seriousness of the condition was also the leading factor associated with obstetric haemorrhage (20.9%, n=9). Inappropriate management was identified in 11.6% (n=5) of MNM with obstetric haemorrhage. In three of these events, women with abnormal placentation were not managed at tertiary healthcare facility. In the remaining two MNM, it seems junior obstetrician performed c-section, despite the women had previous multiple c-sections.

Failure to recognise the seriousness of the condition, (24.1%, n=7), delay in referral to a higher care facility (13.8%,n=4), and failure to involve other specialities (13.8%, n=4) were the common specific factors identified with non-obstetric complications.

#### **7.3.4. Associated factors identified by the International Expert Panel**

The International Expert Panel identified associated factors in 64.7% (n = 101) of the 156 MNM events. Factors related to the healthcare team were the most commonly identified factors, associated with half (n = 78) of the 156 MNM events. Inappropriate management of the condition was the most frequent associated factor (28.2%, n = 44). Failure of the attending healthcare providers to recognise the seriousness of the condition and failure to assess the severity of the condition was associated with 23.7% (n = 37) and 14.7% (n = 23) of the MNM events, respectively.

Factors related to the organisation of care were associated with 26.9% (n = 42) of the 156 MNM events. Factors related to policy and guidelines were the most frequently recorded factors (15.4%, n = 24). Non-availability of guidelines was contributed to 3.2 (n=5) and outdated guidelines to 1.9% (3). Factors related to medication was the second common identified factors (9.6%, n = 15) followed by failure in referral system (5.1%, n = 8).

Factors related to the woman were identified in 22.4% (n = 35) of the 156 MNM events. Non-adherence to prescribed treatment was the most frequently identified

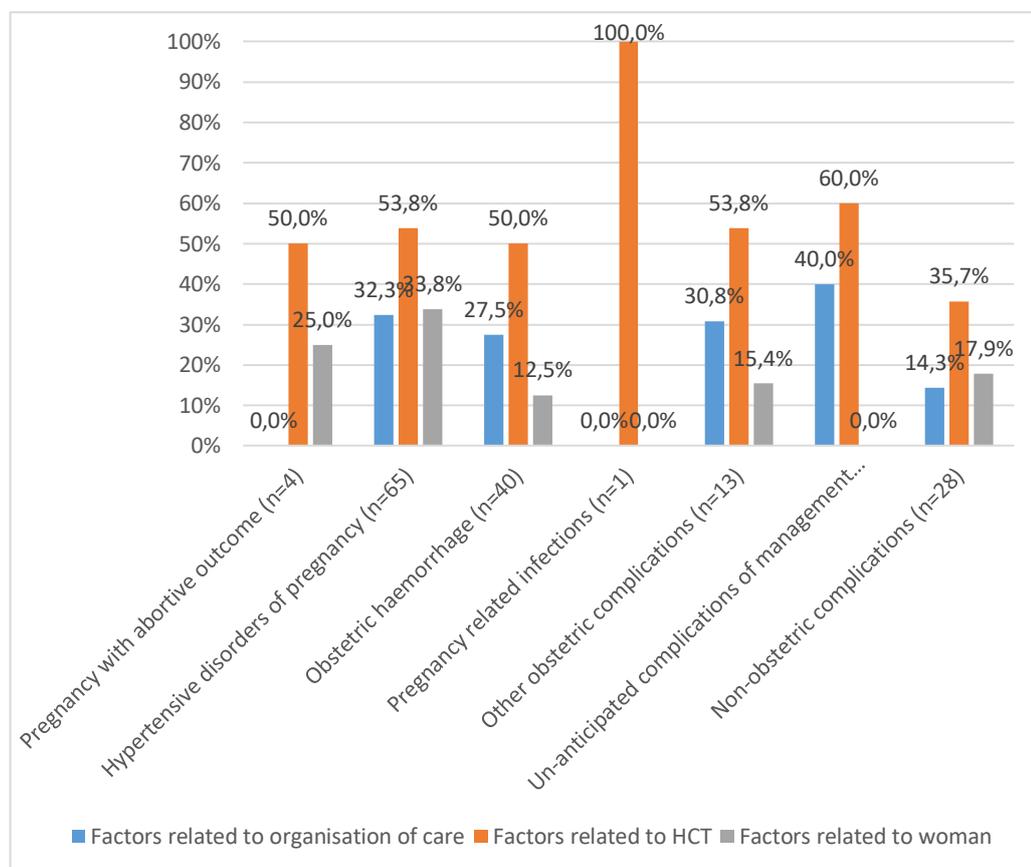
factor (9.6%, n = 15) followed by declined medication or procedure (7.7%, n = 12) and no ANC care (5.8%, n=9). (Table 7.12).

Table 7.12: Factors associated with MNM identified by the International Expert Panel

Factors identified	% (n) of 156 MNM events <sup>9</sup>
<b>Related to the organisation of care</b>	<b>26.9 (42)</b>
Policy and guidelines	15.4 (24)
Non-availability of guidelines	3.2 (5)
Outdated guidelines	1.9 (3)
Non-availability of policy	0.6 (1)
Unspecified	9.6 (15)
<b>Related to medication</b>	<b>7.1 (11)</b>
Non-availability of medication	2.6 (4)
Unspecified	4.5 (7)
<b>Related to referral</b>	<b>5.1 (8)</b>
Non-availability of beds in a higher healthcare facility	1.9 (3)
Transportation problem	2.6 (4)
Unspecified	2.6 (4)
<b>Related to blood</b>	<b>2.6 (4)</b>
Non-availability of blood/blood product	2.6 (4)
<b>Related to staff</b>	<b>5.1 (8)</b>
Poor access to senior staff	3.8 (6)
Inadequate number of staff	0.6 (1)
Unspecified	0.6 (1)
<b>Related to equipment</b>	<b>2.6 (4)</b>
Non-availability of equipment	1.3 (2)
Non- functioning equipment	0.6 (1)
Unspecified	0.6 (1)
<b>Laboratory (non-availability of test)</b>	<b>1.3 (2)</b>
<b>Other</b>	<b>5.1 (8)</b>
<b>Related to the healthcare team</b>	<b>50.0 (78)</b>
<b>Inappropriate management</b>	<b>28.2 (44)</b>
<b>Failure to recognise the seriousness of the condition</b>	<b>23.7 (37)</b>
<b>Failure to assess the severity of the condition</b>	<b>14.7 (23)</b>
<b>Incomplete or delayed assessment of condition</b>	<b>12.8 (20)</b>
<b>Delay in diagnosis of the condition</b>	<b>9.6 (15)</b>
<b>Delay in emergency response</b>	<b>9.6 (15)</b>
<b>Communication failure between the healthcare team</b>	<b>3.8 (6)</b>
<b>Delay in referral to a higher care facility</b>	<b>3.2 (5)</b>
<b>Failure to involve other specialities</b>	<b>1.9 (3)</b>
<b>Others</b>	<b>5.8 (9)</b>
<b>Related to woman herself</b>	<b>22.4 (35)</b>
<b>Non-adherence to treatment</b>	<b>9.6 (15)</b>
<b>Declined medication or procedure</b>	<b>7.7 (12)</b>
<b>No ANC care</b>	<b>5.8 (9)</b>
<b>Delay in seeking care</b>	<b>4.5 (7)</b>
<b>Late booking for ANC care</b>	<b>2.6 (4)</b>
<b>Long distance from a healthcare facility</b>	<b>1.3 (2)</b>
<b>Other</b>	<b>5.1 (8)</b>

<sup>9</sup> Each MNM case can has more than one associated factor.

The panel identified associated factors in all groups of underlying causes of MNM. The lowest reported figure was within the group of non-obstetric complications (46.4%, n = 13). Healthcare team related factors were the predominant identified associated factors within all groups, with the lowest recorded figure for MNM with non-obstetric complications (35.7%, n = 10). Factors related to the organisation of care were highest in unanticipated complications of management (40.0%), followed by hypertensive disorders of pregnancy (32.3%, n = 21). Generally, woman-related factors were the least identified factors, and the highest recorded figure was within hypertensive disorders of pregnancy, with 33.8% (n = 22) (**Figure 7.8**).



*Figure 7.8: Factors associated with MNM and underlying causes identified by the International Expert Panel*

A slight variation was observed in the distribution of associated factors within the ICD-groups of underlying causes. Inappropriate management and failure to recognise the seriousness of the conditions were the common associated specific factors across all ICD-groups of underlying causes. They were the leading factors with cases of hypertensive disorders (32.2%, n=21 each). Similar to the observation

of the National Committee, the common identified failure in the management of these events was related to inappropriate control of hypertension (17), use of magnesium sulphate (=10) and inappropriate fluid balance (n=2), and use of diazepam as a first line drug to control convulsion (n=2).

Inappropriate management was identified in 22.1% (n=9) of MNM with obstetric haemorrhage. Specifically, they were related to inappropriate surgical management of cases with abnormal placentation and cases with multiple c-sections. The cases were not managed at a tertiary care facility and there was a delay in the involvement of an obstetric consultant in the management.

Factors related to policy and guidelines were more commonly identified factors within cases with other obstetric complications (30.8%, n=4) and hypertensive disorders of pregnancy (14.6%, n=16). The highest figure for non-availability of medications was within group of hypertensive disorders of pregnancy, (12.3, n=8), while for failure in referral system, the highest record was within obstetric haemorrhage (12.5%, n=5). Long distance from a healthcare facility contributed to 1.3% (n=2). Both events were related to obstetric haemorrhage. **(Annex 25)**.

#### **7.4. Comparison of associated factors identified at the four different levels of review**

The 156 MNM reviewed at the four levels of review were used to compare associated factors identified. Overall, the highest percentage of MNM events with identified associated factors were recorded by reviewers at the national level (70.5%, n = 110) and the lowest by the reviewers at the hospital level (53.8%, n = 84). The International Expert Panel and regional reviewers recorded associated factors in 64.7% (n = 101) and 56.4% (n = 88) of MNM events, respectively.

Overall factors related to the healthcare team were the most commonly identified factors by all reviewers except for the Regional Committee **(Figure 7.9)**. The International Expert Panel (50.0%, n = 78) and national reviewers (44.2%, n = 69) identified associated factors more compared to the hospital (30.8%, n = 48) and regional reviewers (30.1%, n = 47). Similarly, factors related to the organisation of care were reported by the expert panel and national reviewers (26.9%, n = 42) more in MNM events than by other panels.

There was an observed variation in the proportion of MNM events with factors relating to the woman herself. The regional reviewers recorded the highest

percentage of MNM events with these factors (34.0%, n = 53) followed by the national reviewers (32.1%, n = 50). This percentage was 22.4% (n = 35) for the International Expert Panel and 19.9% (n = 31) for the hospital reviewers.

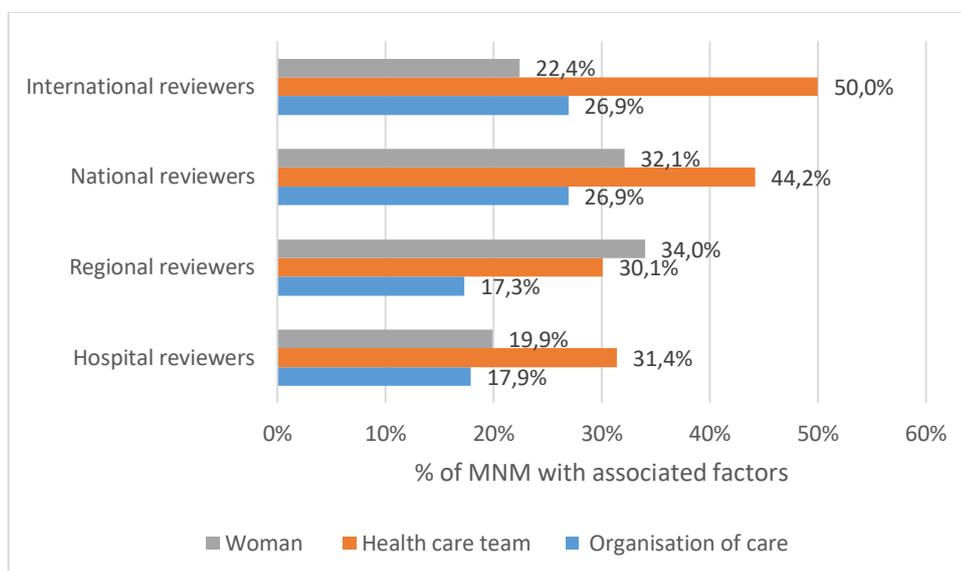


Figure 7.9: Comparison of associated factors identified by different reviewers

**Table 7.13** compares the specific factors identified by reviewers at different levels. It was observed that there was a difference in the frequency of specific factors identified by different groups of reviewers. For instance, hospital reviewers identified specific factors related to the organisation of care more often than other review panels, except for those related to policy and guidelines, while the national and expert panel had higher recorded figures for factors related to the healthcare team.

However, in general, it seems the reviewers agreed regarding the leading factors associated with MNM. Inappropriate management and failure to recognise the seriousness of the condition were the leading associated factors recorded at all levels in the category of healthcare team related factors. All reviewers agreed that non-adherence of the woman to prescribed treatment was the main associated factor related to the woman herself. In the category of organisation of care, the International Expert Panel identified factors related to policy and guidelines as the leading factors. The national reviewers had the highest recorded figure also for factors related to policy and guidelines, as well as for those related to staff. Factors related to staff were also the leading contributed factors reported by the hospital and regional reviewers.

Table 7.13: Comparing specific factors associated with MNM by different reviewers

Factors identified	Hospital % (n)	Regional	National	International
Related to organisation of care	17.9 (28)	17.3 (27)	26.9 (42)	26.9 (42)
Related to policy and guidelines	1.9 (3)	4.5 (7)	15 (9.6)	24 (15.4)
Non-availability of policy	-	1.3 (2)	3.2 (5)	0.6 (1)
Non-availability of guidelines	1.9 (3)		2.6 (4)	3.2 (5)
Outdated guidelines	-	0.6 (1)	1.9 (3)	1.9 (3)
Un-specified	-	-	-	9.6 (15)
Related to medication	5.1 (8)	1.3 (2)	1.3 (2)	7.1 (11)
Non-availability of medication	0.6 (1)	1.3 (2)	0.6 (1)	2.6 (4)
Un-specified	4.5 (7)	-	0.6 (1)	4.5 (7)
Related to referral	1.9 (3)	1.9 (3)	5.1 (8)	5.1 (8)
Non-availability of beds in higher healthcare facility	-	1.3 (2)	1.9 (3)	1.9 (3)
Transportation problem	0.6 (1)	-	1.9 (3)	2.6 (4)
Other	1.3 (2)	0.6 (1)	1.3 (2)	0.6 (1)
Related to blood	5.1 (8)	2.6 (4)	3.2 (5)	2.6 (4)
Non-availability of blood/ blood products	5.1 (8)	2.6 (4)	2.6 (4)	2.6 (4)
Un-specified	-	-	0.6 (1)	-
Related to staff	8.3 (13)	5.1 (8)	9.6 (15)	5.1 (8)
Inadequate number of staff	5.1 (8)	3.2 (5)	5.1 (8)	0.6 (1)
Poor access to senior staff	3.2 (5)	2.6 (4)	3.8 (6)	3.8 (6)
Other	1.3 (2)	-	1.9 (3)	0.6 (1)
Related to equipment	4.5 (7)	5 (3.2)	3.8 (6)	2.6 (4)
Non-availability of equipment	3.8 (6)	5 (3.2)	3.2 (5)	1.3 (2)
Non-functioning equipment	-	-	0.6 (1)	0.6 (1)
Unspecified	-	-	-	0.6 (1)
Related to laboratory	-	1.3 (2)	1.9 (3)	1.3 (2)
Non-availability of test	-	0.6 (1)	0.6 (1)	1.3 (2)
Inaccurate laboratory test results	-	-	1.3 (2)	-
Delay in accessing results	-	0.6 (1)	-	-
Long distance from healthcare facility	-	1.3 (2)	1.9 (3)	1.3 (2)
Other	0.6 (1)	1.9 (3)	5.8 (9)	5.1 (8)
Related to healthcare team	31.4 (49)	30.1 (47)	44.2 (69)	50.0 (78)
Inappropriate management	7.7 (12)	7.1 (11)	16.7 (26)	28.2 (44)
Failure to recognise of the seriousness of the condition	5.1 (8)	12.2 (19)	20.6 (40)	23.7 (37)
Failure to assess the severity of the condition	-	4.5 (7)	18 (11.5)	14.7 (23)
Incomplete or delayed assessment of condition	3.2 (5)	5.1 (8)	8.3 (13)	12.8 (20)
Delay in diagnosis of the condition	6.4 (10)	7.1 (11)	10.3 (16)	9.6 (15)
Poor quality of care during transferring the woman to a higher healthcare facility	4.5 (7)	-	-	-
Delay in emergency response	1.3 (2)	2.6 (4)	5 (3.2)	9.6 (15)
Failure in monitoring the severe condition	2.6 (4)			
Communication failure between healthcare team	-	2.6 (4)	5 (3.2)	3.8 (6)
Delay in referral to higher care facility	7.7 (12)	5.1 (8))	9.6 (15)	3.2 (5)
Failure to involve other specialities	0.6 (1)	0.6 (1)	3.2 (6)	1.9 (3)
Others	5.8 (9)	7.1 (11)	10.3 (16)	5.8 (9)
Related to woman herself	19.9 (31)	34.0 (53)	32.1 (50)	22.4 (35)
Non-adherence to treatment	8.3 (13)	10.9 (17)	10.9 (17)	9.6 (15)

Factors identified	Hospital % (n)	Regional	National	International
Declined medication or procedure	2.6 (4)	5.8 (9)	4.5 (7)	7.7 (12)
No ANC care	1.3 (2)	4.5 (7)	7.1 (11)	9 (5.8)
Delay in seeking care	1.9 (3)	12.2 (19)	9.6 (15)	4.5 (7)
Late booking for ANC care	1.3 (2)	7.1 (11)	8.3 (13)	4 (2.6)
Long distance from healthcare facility	-	1.3 (2)	1.9 (3)	1.3 (2)
Other	3.8 (6)	5.8 (9)	9.0 (14)	5.1 (8)

## 7.5. Lessons to be learned for future improvement of care

At the end of each review of MNM event, the reviewers were requested to list lessons to learned to prevent a similar event in future. Analysis of these lessons revealed they could be grouped into two categories; lessons to learned for the healthcare system and lessons for clinical management. The former should be addressed by policymakers and directors at national, regional and hospital levels, while the latter should be taken by healthcare providers to improve their clinical practice.

### 7.5.1. Lessons learned identified by hospital reviewers

From reviewing 313 MNM, the hospital reviewers identified 52 lessons related to clinical management and 10 lessons to improving the healthcare system. **Table 7.14** illustrates the top five identified lessons in each category. Within the group of the healthcare system, updating the guidelines for the management of common obstetric complications and developing referral guidelines for obstetric emergency were the commonly identified lessons (3.2%, n=10). The reviewers called for urgent need to conduct obstetric emergency drills and training healthcare providers on recognition and management of severe complications in 2.9% (n=9) of the events. They also called on ensuring an adequate number of staff at each healthcare level and ensuring the availability of life-saving medication and equipment.

Early involvement of a multidisciplinary team in management in the management of a woman with medical disorders and those with obstetric complication was the most frequently identified lessons for clinical practice (13.1%, n=41). The reviewers stressed the importance of recognition of hypertensive disorders of pregnancy by measuring BP and performing urine analysis during each ANC with an early referral of pre-eclampsia to an obstetric led unit (8.3%, n=26). They also stressed on early confirmation and referral of a patient with the invasive placenta to tertiary care centre (6.1%, n=19). They called for early involvement of senior doctors in the

management of high-risk pregnancy and counselling these women on warning signs during pregnancy (6.1%, n=19).

*Table 7.14: lessons to be learned identified by hospital reviewers*

Identified lesson to be learned		% (n) of MNM with identified lesson
<b>For healthcare system</b>		
1	There is a need to have updated guidelines for the management of common obstetric complications in particular for severe pre-eclampsia/ eclampsia, abnormal placentation, SCD, peripartum cardiomyopathy.	3.2 (10)
2	Having clear referral guidelines and protocols is necessary for obstetric emergency	3.2 (10)
3	An urgent need to conduct obstetric emergency drills and training healthcare providers on recognition and management of severe complication such as severe pre-eclampsia, severe obstetric haemorrhage, etc.	2.9 (9)
4	Ensure availability of adequate numbers of staff (obstetrician, midwives and nurses) in particular senior-level staff at all levels of healthcare facilities	2.6 (8)
5	Ensure availability and sustainable supply of life-saving medication and equipment in particular magnesium sulphate at primary healthcare level and Bakri balloon in regional hospitals.	2.2 (6)
<b>For Clinical management</b>		
1	Early involvement of a multidisciplinary team in the management of a woman with medical disorders and those with obstetric complication is necessary to improve the outcome of mother and newborn	13.1 (41)
2	Measure and record of BP correctly and urinalysis at each antenatal visit, intrapartum and postpartum. Woman with hypertensive disorders needs regular check-up and monitoring. They need to be referred early from lower levels of healthcare to an obstetric-led unit. Healthcare providers need to be alert for signs of deterioration and eclampsia.	8.3 (26)
3	Patients with suspicion of the invasive placenta should have Magnetic resonance imaging (MRI) to confirm the diagnosis. Those with placenta previa/invasive placenta need to be referred to a tertiary care centre.	6.1 (19)
4	Early involvement of senior doctors (consultant) in the management of high-risk pregnancy and women with complication improve the outcome. For these women, a plan of care/management from the time of first ANC visit should be discussed with the senior doctor.	6.1 (19)
5	To provide health education and counselling for women with high-risk pregnancy such as SCD, pre-eclampsia on recognition of warning signs to avoid delay in seeking care. Involvement of family member/s should be encouraged in health education and counselling.	6.1 (19)

### **7.5.2. Lessons learned by the Regional Maternal Mortality Committee**

From reviewing 290 MNM events, the Regional Maternal Mortality Committee listed 38 lessons to be learned for clinical practice and 10 lessons for the healthcare system. The frequently recorded lesson was the need to increase public and women awareness' of the importance of ANC and warning signs during pregnancy (9.0%, n=26). Similar to the hospital reviewers, they called for conducting obstetric drills and ensuring the availability of an adequate number of staff and life-saving medication and equipment in all healthcare levels (**Table 7.15**). On the clinical management, they emphasised on early identification of high-risk pregnancy (7.1%, n=21), improving documentation in the patient medical file (5.5%, n=16) and early

confirmation and referral of patients with the invasive placenta to tertiary care centre (5.5%, n=16).

*Table 7.15: Lessons to be learned identified by regional reviewers*

Identified lesson to be learned		% (n) of MNM with identified lesson
<b>For healthcare system</b>		
1	There is a need to increase public and women awareness about the importance of early booking and follow-up with antenatal care clinic, as well as warning signs during pregnancy.	9.0 (26)
2	There is an urgent need to conduct obstetric emergency drills on obstetric emergency and training healthcare providers in early recognition and management of severe obstetric complications. Head of obstetrics and gynaecology should coordinate with the Department of Woman and Child and other related departments to organise such training.	5.5 (16)
3	Reviewing the number of staff in maternity units and ensuring the availability of adequate numbers of staff in particular senior-level staff at all levels of healthcare facilities. There is a need to ensure the availability of a sufficient number of obstetric consultants in all maternity units and increase the number of midwives to deliver one to one care.	3.1 (9)
4	Ensure availability and sustainable supply of life-saving medication and equipment in particular magnesium sulphate at primary healthcare level and Bakri balloon, blood exchange machine at regional hospitals. Local mechanism with focal person needs to be established to monitor the supply of these essential medications and equipment at each healthcare facility.	2.4 (7)
5	There is a need to review and update the current guidelines for primary healthcare level on the management of the hypertensive disorder in pregnancy, especially the management of eclampsia. There is a need to expand the guidelines for secondary care level on antenatal care to include management of asthma during pregnancy, and invasive placenta.	2.4 (7)
<b>For Clinical management</b>		
1	Identify women with high-risk pregnancy for early referral to secondary or tertiary care level based on risk factors. There should be a plan for antenatal care and delivery for these pregnancies.	7.2 (21)
2	Improve documentation of care given and events in the maternal Health Record and the patient medical record. Vital signs, the sequence of events and monitoring instruction should be recorded clearly to facilitate taken action.	5.5 (16)
3	Patient with suspected invasive placenta should have MRI confirmation by 28-30 weeks of gestation. Those with morbidity adherent placenta should be managed in a tertiary care centre.	5.5 (16)
4	A senior obstetrician should be involved early in complicated surgery, management of high-risk pregnancy and patient with severe complication/s.	4.8 (14)
5	Early recognition of severe complication with early intervention prevent deterioration of the patient condition and improve maternal and newborn outcome.	4.8 (14)

### **7.5.3. Lessons learned identified by the National Maternal Mortality Committee**

From reviewing 156 MNM, the National Maternal identified 11 and 39 lessons to be learned for the healthcare system and for improving clinical management, respectively. They also identify need to update the current guidelines on National Antenatal, Childbirth and Postpartum Care guidelines and conducting obstetric

emergency drills (6.4%, n=10). They also called to increase public, families and women awareness about the importance of ANC care and complications arising during pregnancy (5.8%, n=9), and ensure availability of life-saving medication and equipment (2.6%, n=4) (**Table 7.16**).

On clinical management, they emphasised that healthcare providers need to follow the national guidelines (10.3%, n=16), and to involve senior in the management of women with high-risk pregnancy (9.6%, n=15). They stressed on the importance of using monitoring system (8.3%, n=13), multidisciplinary team management of complex cases (8.3%, n=13) and counselling women with high-risk pregnancy (7.7%, n=12).

*Table 7.16: Lessons to be learned by the national reviewers*

Identified lesson to be learned		% (n) of MNM with identified lesson
<b>For healthcare system</b>		
1	Update the current National Antenatal, Childbirth and Postpartum Care guidelines in particular management severe pre-eclampsia. Expand the guidelines to include management of peripartum cardiomyopathy, SCD in pregnancy, abnormal placentation, and Caesarean scar pregnancy.	6.4 (10)
2	An urgent need to conduct obstetric emergency drills. Train healthcare providers at all levels of public healthcare and private healthcare facilities on recognition and management of severe complication in particular eclampsia.	6.4 (10)
3	Increase public, families and women awareness about the importance of early ANC booking, ANC follow-up and complications arising during pregnancy.	5.8 (9)
4	Ensure availability and sustainable supply of life-saving medication and equipment in particular magnesium sulphate at primary healthcare level private healthcare facilities, Bakri balloon and cell saver in regional hospitals.	2.6 (4)
5	There should be clear referral guidelines and protocols for obstetric emergency	1.9 (3)
<b>For Clinical management</b>		
1	Healthcare provider should follow the national guidelines for the management of hypertensive disorders of pregnancy to prevent maternal morbidity and mortality.	10.3 (16)
2	Senior healthcare providers need to be involved early in deciding management of obstetric complication to avoid deterioration. A senior obstetrician should be available 24 hours in all maternity units.	9.6 (15)
3	Healthcare providers should use monitoring systems such as partogram and obstetric early warning system to monitor vital signs and record interventions. The sequence of events, interventions and operation findings should be recorded documentation clearly in the patient medical record.	8.3 (13)
4	There should be early involvement of a multidisciplinary team in the care of high-risk pregnancies, in particular, those with medical disorders such as SCD and cardiac diseases. The multidisciplinary team approach is also necessary for the management of obstetric emergencies to improve the outcome.	8.3 (13)
5	Counselling women with a high-risk pregnancy should be counselled about their condition, warning signs during pregnancy, management plan. Counselling during postpartum period should include family planning and plan for future pregnancy.	7.7 (12)

#### **7.5.4. Lessons learned by the International Expert Panel**

The International Expert Panel recorded 40 lessons for improving clinical practice, and five lessons for a healthcare system with the most frequently recorded lesson was related to guidelines. The panel urged the country to review and update the guidelines on pre-eclampsia/eclampsia, invasive placentation, PPH, thromboprophylaxis, hyperemesis gravidarum in 29.5% (n=46) of the 156 MNM events. They called for multidisciplinary team training in obstetric emergencies in 16.7% (n=26). They advised auditing cases with severe complications with the dissemination of success stories and lessons learned (1.3%, n=2). Similar to other reviewers, they stressed to ensure availability of magnesium sulphate in all healthcare facilities (1.3%, n=2) (**Table 7.17**).

The most frequently identified lesson for clinical management was reviewing and improving documentation of timelines of events, vital signs, drugs, and fluid balance (12.8%, n=20). Healthcare providers should use a monitoring tool such as the Modified Early Warning System (MEWS) to facilitate comparisons, interpretation and action taken. Improving the assessment of patients with hypertensive disorders and reviewing the management of fluid balance in those with pre-eclampsia was the second common recorded lesson with 6.4% (n=10) each. The panel also called to have a multidisciplinary team to manage complex patient (5.8%, n=9) and to improve risk assessment during the first ANC visit (5.1%, n=8).

Table 7.17: Lessons to be learned by the international reviewers

Identified lesson to be learned		% (n) of MNM with identified lesson
<b>For healthcare system</b>		
1	Review/introducing guidelines for management of pre-eclampsia/eclampsia (including fluid management), invasive placentation, PPH, thromboprophylaxis, hyperemesis gravidarum,	29.5 (46)
2	Multidisciplinary team training (including anaesthetists) and competence assessment in obstetric emergencies in particular severe pre-eclampsia/eclampsia with the provision of an emergency trolley containing algorithms and drugs. There should be training in situational awareness and surgical techniques to reduce obstetric haemorrhage.	16.7 (26)
3	Audit cases with severe maternal complications, disseminate experiences, success stories and lessons learnt locally.	1.3 (2)
4	Ensure the availability of life-saving medication in particular magnesium sulphate in all healthcare facilities.	1.3 (2)
5	There should be clear referral guidelines and protocols for high-risk pregnancies and obstetric complications.	0.6 (1)
<b>For Clinical management</b>		
1	Timelines of events, vital signs, estimated blood loss, drugs, fluid balance should be recorded clearly to highlight the requirement for action. Use tool similar to the Modified Early Warning System so that vital measurements can be charted on a timeline and comparisons, interpretation and action taken accordingly	12.8 (20)
2	For early recognition of symptoms of pre-eclampsia, improved assessment of the patients with hypertensive disorders of pregnancy. A clear plan of management, including investigations and treatment, should be started in all levels of care	6.4 (10)
3	In the management patient with severe pre-eclampsia, review fluid management and use of fluid balance chart. Healthcare providers should be more rigour in fluid restriction, avoiding fluid boluses and frusemide for oliguria in cases of severe pre-eclampsia.	6.4 (10)
4	There should be a multidisciplinary team managing complex patients. One senior doctor should be responsible for leading and coordinating the care provided by the team.	5.8 (9)
5	Improve risk assessment at booking visit for ANC. There should be a clear care plan for the woman on the first hospital appointment, including mode of delivery.	5.1 (8)

## 7.6. Comparing lessons to be learned identified by different groups of reviewers

### 7.6.1. Lessons to be learned for the healthcare system

The 156 MNM reviewed at the four levels of review were used to compare the identified lessons to be learned. **Annex 26** compares the five main lessons learned identified by reviewers at different levels. In general, the different groups of reviewers agreed on the main lessons to be learned for improving the healthcare system with variation in the frequency of these identified lessons. There was a higher similarity between national and international panels where they agreed on four out of five listed lessons to be learned.

All reviewers agreed on the need to updated guidelines on management obstetric complications and conducting training on obstetric emergency. The international panel identified these needs more frequently compared to country reviewers.

Hospital and regional reviewers stressed more on increasing public and women awareness about ANC care and warning signs during pregnancy. They also called to ensure an adequate number of staff Ensuring availability and sustainable supply of life-saving medication and equipment was recorded by regional, national and international panels. Having clear referral guidelines was identified as a priority by all reviewers except regional reviewers.

### **7.6.2. Lessons to be learned for improving clinical management**

Overall, there were differences in the recorded lessons to be learned for improving clinical management by different reviewers. All reviewers agreed on the importance of Multidisciplinary team approach in the management of women with medical disorders and those with a complication with slight variation in the recorded frequency. It was the most commonly listed lesson by hospital reviewer with 12.2% (n=19) while it was recorded by the national, regional and international reviewers in 8.3% (13), 7.7% (11) and 5.8% (9), respectively.

Use of monitoring system such as MEWS for early recognition of complications was the most frequent identified lesson by the international reviewers (12.8%, n=20). The use of monitoring systems was the third frequently recorded lesson by the national reviewers, and it was recorded in 8.3% (n=13) of the MNM events. Regional reviewers stressed on improving documentation of care in 7.1% (n=11), without specifying the use of any tool. In contrast to international reviewers, the country reviewers stressed on involving senior obstetrician in the management of complicated cases as well as on health education and counselling of women.

Hospital, national and international reviewers called for improving the management of women with hypertensive disorders of pregnancy. However, difference was observed in formulating the specific action. The international reviewers focused more on specific aspects of clinical care and pointed to a wider action in the whole care pathway the woman received compared to country reviewers. For example, the hospital reviewers, specified measuring BP, urinalysis, early referral from a lower level to a higher level and recognition of deterioration of the condition. The international panel called for improving assessment, having a clear plan for management and reviewing fluid management in the patient with pre-eclampsia. On the other hand, the national reviewers emphasised on following the national guidelines.

## 7.7. Chapter summary

This chapter reported on the findings of the assessment of QoC and factors associated with MNM (factors in the organisation of care, healthcare team, and related to the woman herself) and compared the findings of reviewers at the four levels of review: hospital, regional, national, and International Expert Panel.

Overall, based on the reviews, in more than 40.0% of MNM events, the provided care was considered to be good. However, there was a variation in the assessment of QoC between the reviewers at the four levels of review. The national reviewers and expert panel identified more MNM events in which improvement in QoC might have made a difference to the outcome compared to the hospital and regional reviewers, with 34.4% (n = 54) and 36.5% (n = 57) compared to 10.9% (n = 17) and 19.9% (n = 31), respectively.

Examining the assessment of QoC by groups of underlying causes of MNM reveals that MNM events due to hypertensive disorders or obstetric haemorrhage were considered among the top three most frequent groups by all reviewers where an improvement in the QoC could have made a difference to the outcome.

When the level of agreement between the assessment of the standard of QoC was compared between different review panels, there was substantial agreement in the assessment of care between hospital and regional reviewers, which was statistically highly significant ( $\kappa = 0.7$ ,  $p$ -value  $< 0.001$ ). The regional reviewers had a statistically significant slightly agreement with the national reviewers ( $\kappa = 0.1$ ,  $p = 0.001$ ). There was a slight agreement between hospitals reviewers and the national reviewers ( $\kappa = 0.1$ ,  $p = 0.027$ ). The agreement between hospitals reviewers and the regional reviewers with International Expert Panel were not statistically significant. There was a slight agreement between the national reviewers and the International Expert Panel which was statistically significant ( $\kappa = 0.1$ ,  $p = 0.008$ ).

Overall, the national and International Expert Panel reported a higher proportion of MNM events with associated factors compared to the hospital and regional reviewers. Factors related to the healthcare team were the most commonly identified associated factors except by regional reviewers.

Inappropriate management of cases and failure to recognise the seriousness of the severe condition were the leading specific factors related to the healthcare team. Non-adherence of the woman to prescribed treatment and not taking medication

was the leading factor related to the woman herself. The national and expert panel recorded factors related to non-availability or outdated guidelines/policy as the main factors related to the organisation of care. Staff related factors such shortage of staff or poor access to senior staff were commonly identified factors associated with MNM events by national, regional, and hospital reviewers.

In general, hospital reviewers reported a higher frequency of specific factors related to the non-availability of blood, equipment, referral system, and medication. The national and International Expert Panel recorded a higher frequency for factors related to the healthcare team who attended the case of MNM.

## 8. Discussion

The discussion format for scientific results by Docherty and Smith (1999) was used to discuss the main findings from this study. Specifically, the main findings by study objectives, strengths, limitations and a comparison of the study findings with those in the literature are presented. To take the context into account and when it is possible, the results of the study is compared with the literature from Oman, countries from the same region (the Middle East and North Africa (MENA)) and countries with the same World Bank classification (high-income countries).

### 8.1. Main findings

In countries with few maternal deaths, review of MNM can complement maternal deaths review to identify areas of substandard care. Oman has a relatively small number of maternal deaths, but the majority are preventable, and the burden of severe maternal morbidity was unknown before this study. Thus, the study aim was to introduce MNM review to Oman. Specifically, the study was set out to determine the incidence of MNM, causes of, contributory conditions to, and factors associated with MNM, measuring the standard of care, and making recommendations for further improvement of maternity care in Oman. The WHO ICD-MM classification of death during pregnancy, childbirth, and puerperium was used to develop identification criteria for MNM. A survey was combined with an in-depth review of cases to fulfil the study objectives (**Figure 8.1**). The cases were reviewed by hospital, regional, national, and international review panels. The main findings were as discussed below.

#### 8.1.1. Numbers and indicators

During the twelve months of data collection, there were 78,918 live births delivered by 78,446 women in the 23 participating hospitals, representing 90.0% of total deliveries in Oman. A total of 1,731 women were identified with potentially life-threatening conditions in these hospitals, of whom there were 312 MNM with 313 MNM events, leaving 1,419 who met the PLTC definition only. During the same period, a total of 25 maternal deaths were reported from the participating hospitals.

The incidence of PLTC was 18.1 per 1,000 women giving birth (95% CI 13.8;22.4). The ratio of PLTC to MNM was 4.5 (95% CI 3.3;5.8), while the incidence of MNM was 4.0 per 1,000 women giving birth (95% CI 2.7;5.2).

The MNM ratio was 4.0 per 1000 (95% CI 2.7;5.2) live births, and the SMO ratio was 4.3 per 1000 (95% CI 3.0;5.5) live births. The ratio of MNM to MD was 10.3:1 (95% CI 4.6;16.0) and the MI was 7.4% (95% CI 6.0;8.0).

### **8.1.2. Characteristics of MNM and comparison with PLTC**

Compared with PLTC, there were statistically significant differences between women with MNM and those with PLTC in age, gravidity, parity and history of pre-existing medical disorders, as described below.

Women with MNM were slightly younger than those with PLTC, with mean ages of 30.3 years (SD = 6.3) and 31.2 years (SD = 5.8) (one-way ANOVA  $F(1, n = 1727) = 5.6, p = 0.018$ ).

There were more women undergoing their first pregnancy among the MNM group than among the PLTC group, with 39.7% ( $n = 99$ ) compared to 24.9% ( $n = 354$ ) (one-way ANOVA test  $F(1, n = 1,727) = 6.1, p = 0.014$ ). After adjusting for other previous pregnancy characteristics (number of previous abortions, number of previous stillbirths, and number of previous caesarean sections), the odds ratio of a near-miss compared to PLTC is 6.4% lower for every increase in gravidity, and was statistically significant (adjusted odds ratio = 0.936 (95% CI 0.877-0.998)).

The odds ratio of woman having MNM compared to PLT if she had a previously diagnosed medical disorder was 1.5 higher (95% CI 1.2;2.0).

### **8.1.3. Causes of MNM**

Hypertensive disorders of pregnancy were the leading cause of MNM, accounting for more than 40% of all MNM events. This was followed by obstetric haemorrhage, with more than 20%, and non-obstetric complications, which accounted for up to 18% of the MNM events.

In terms of specific causes of MNM, severe pre-eclampsia, eclampsia, SCD disease, and adherent placenta were the most commonly identified causes by all reviewers, with slight variation observed in this order.

A high level of agreement was observed between the different review panels in assigning the ICD-MM group for the underlying cause of MNM, with kappa coefficient values of 0.9 between hospital and regional reviewers, 0.9 between hospital and national reviewers, 0.8 between hospital and international review panel, 0.8 between regional and national review panels, 0.8 between regional and international review panels, and 0.8 between national and international review panels.

- *Contributory conditions of MNM*

Review panels identified contributory conditions in more than 50.0% of MNM events.

Maternal conditions (included obstetric and medical conditions of the mother that could have contributed to or aggravated severe complications) were the most common identified contributing condition by all reviewer panels. In total, these contributed to more than half of MNM events. A previous caesarean section was the leading condition, recorded in around one-fifth of MNM events.

This was followed by medical disorders, including anaemia, diabetes, and the group of “other” medical disorders, with the same distribution of about 20.0% each. Grand multiparity was identified and recorded in 1 in 5 MNM events.

#### **8.1.4. Standard of care for MNM**

In more than 40% of MNM events the care provided was considered good.

The International Expert Panel and national reviewers identified more MNM events in which improvement in QoC might have made a difference to the outcome compared to the hospital and regional reviewers, with 36.5% (n = 57) and 34.4% (n = 54) versus 10.9% (n = 17) and 19.9% (n = 31) respectively.

MNM events with hypertensive disorders or obstetric haemorrhage were considered by all reviewers as the most occurring groups with identified opportunities for improvement in the QoC.

There was a variation in the assessment of QoC between different review panels. A substantial statistically significant agreement was observed between the hospital and regional panels ( $\kappa = 0.7$ ,  $p$ -value  $< 0.001$ ). There was slight agreement between national and International Expert Panels ( $\kappa = 0.1$ ,  $p = 0.008$ ).

### **8.1.5. Factors associated with MNM**

National reviewers and the International Expert Panel identified more associated factors compared to hospital and regional reviewers, with 70.5% and 64.7% compared to 53.8% and 56.4%, respectively.

Factors related to the healthcare team were the most commonly identified associated factors. Inappropriate management of cases (prescription of medication, interventions, surgery, etc.) was the leading factor associated with up to 28.2% of all MNM events, followed by a failure to recognise the seriousness of the severe condition (25.6%).

Patient non-adherence to prescribed treatment and declined procedure or treatment were the leading patient-related factors and were identified in up to 10.9% and 7.7% of MNM events, respectively.

Factors related to non-availability or outdated guidelines/policy were the main factors related to the organisation of care, associated with 14.1% of MNM events. This was followed by factors related to staff (an inadequate number of care providers or poor access to senior staff), recorded in up to 9.6% of MNM events. Factors related to the referral system were identified in up to 5.8% of all MNM events.

The main findings related to the study objectives and methodology are summarised in **Figure 8.1**.

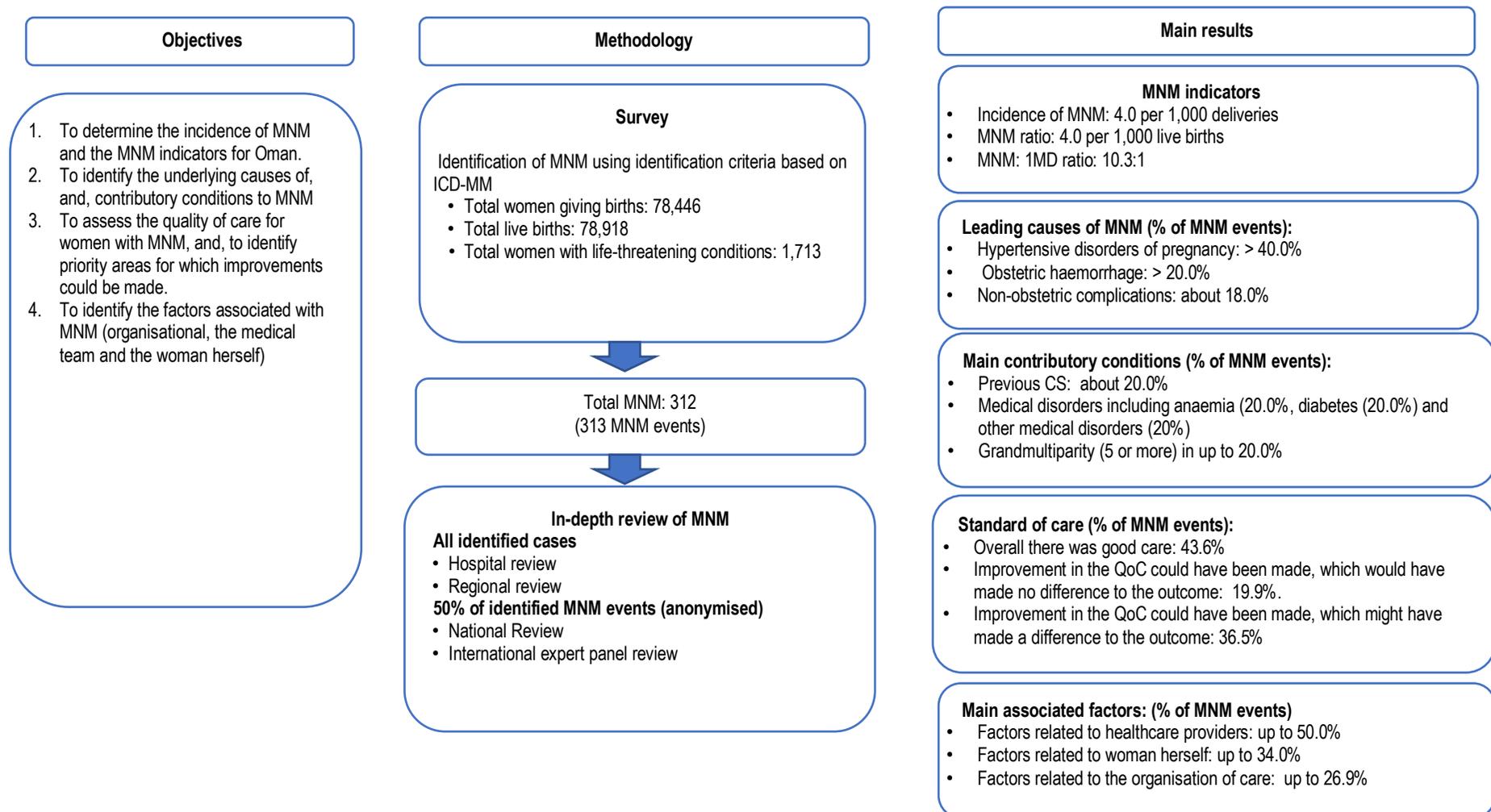


Figure 8.1: Summary of study objectives, methodology and main findings

## **8.2. Interpretation and discussion of the main findings**

### **8.2.1. Definition of MNM**

The WHO working group on Maternal Mortality and Morbidity Classifications suggested a definition of MNM formulated in line with definitions of maternal deaths definition and classification: “the proposal reconciles the above-mentioned definitions within a new definition that is aligned with the ‘maternal death’ definition” (Say, Souza and Pattinson, 2009, p.289). However, it was surprising that the current WHO definition of MNM does not exclude accidental and coincidental causes of MNM, as is the case with the definition of maternal death (WHO, 2011). To keep in line with the definition of maternal death, in this study the WHO definition was used to define MNM, but the severe maternal morbidities due to accidental causes were excluded when estimating the incidence of MNM and when calculating the indicators. We believe that having a mutually consistent definitions of maternal death and MNM is important to facilitate comparison of causes of these two severe maternal outcomes.

Reporting and reviewing severe maternal morbidity as well as maternal death due to accidental and coincidental causes are necessary, but applying the same definition to both severe outcomes might be more accurate, in particular when calculating MNM indicators. The current WHO approach proposes the ratio between MNM and maternal deaths as indicator of QoC. Therefore, it is important to include cases with similar causes from both groups when calculating these indicators. In the literature, some researchers (Jabir et al., 2013; Bashour et al., 2015) reported MNM due to accidental and coincidental causes. Jabir et al. (2013) included these cases in calculating MNM indicators. Other researchers (Ali et al., 2011; Madeiro et al., 2015; Oladapo et al., 2016) did not report these causes. Agreeing and reporting a clear definition facilitates comparison of reported figures in the literature in future.

### **8.2.2. Identification criteria for MNM**

#### *8.2.2.1. Selection of the identification criteria for MNM*

As discussed in chapters 1, 2 and 3, there are five main categories of criteria for the identification of MNM: disease-specific, management-based, organ dysfunction, mixed, and WHO criteria. Each category has its advantages and disadvantages. This study used criteria based on the principle of the disease-specific criteria group, which have been criticised as being less specific and difficult to standardise (Say, Souza and Pattinson, 2009). In a busy maternity ward with a shortage of human

resources, it is much easier for healthcare providers to use specific conditions/diseases as a starting point to identify cases of interest (rather than alternatives such as identifying markers of organ failure). We demonstrated in this study that it is possible to standardise and specify the severe morbidities included in MNM study or surveillance using an internationally acceptable definition.

This study used the approach used in high-income countries with a long running surveillance of severe maternal morbidity, such as the UK (Knight et al., 2014), Scotland (Marr, Lennox and McFadyen, 2014), Australia (Halliday et al., 2018) and Belgium (Vandenberghe et al., 2017). These surveillance systems use specific identification criteria for each case of severe morbidity causing the MNM rather than using the same criteria for all causes (the latter of which is the WHO approach). This allows more flexibility in changing the conditions under study when new diseases emerge. For example, in 2009 the UK system was able to conduct a rapid study of the H1N1 influenza pandemic (Knight et al., 2014).

#### *8.2.2.2. ICD-MM as a framework for the development of identification criteria for MNM*

A unique feature of this study was the use ICD-MM as a framework for the criteria for the identification of MNM for each morbidity group. This facilitated the comparison between causes of maternal death and MNM by using the same classification system. Say, Souza and Pattinson (2009) in their publication of the WHO criteria had indicated that development of the WHO MNM approach was in line with development of the ICD-MM classification system for causes of maternal death (WHO,2012) to ensure the two systems would be consistent and follow the same classification. However, it is not clear how the ICD-MM was reflected in the development of the WHO MNM identification criteria and approach (WHO, 2011).

In this study concerning Oman, the first seven ICD-MM groups of causes were selected, after which a total of 47 morbidities were selected as potentially life-threatening conditions, including all the ICD-MM groups. This was based on the review of the literature and through consensus and discussion with national and international experts as described in the study methodology (chapter 3). The use of the ICD-MM groups as a starting point for the identification of MNM cases simplified the identification process for the healthcare providers. It also facilitated the recognition and classification of underlying causes of MNM by health workers and reviewers. The results show minimal variation in the reported proportion of MNM events for each ICD-MM group by healthcare providers in the participating hospitals

and the reviewers. If both healthcare providers and reviewers use the ICD-MM as a framework for reporting and assigning cause for MNM, this is likely to improve the accuracy in reporting the cause of both MNM and maternal death in future.

A striking observation when using ICD-MM to develop the MNM criteria and to assign underlying causes in this study was the limitations with regard to the group of unanticipated complications of management. As per the current version of ICD-MM (WHO, 2012), the causes listed under this group are limited to complications of anaesthesia only. This group ideally should include all causes resulting from complications of management, examples of which identified in this study include severe reaction to mismatched blood transfusion, complications related to artificial rupture of membrane, complications of augmentation of labour, or complications related to surgical procedures.

#### *8.2.2.3. Validation of the criteria for identification of MNM*

Validation of testing methods to establish their accuracy is usually carried out by comparing results against gold standard testing methods, involving comparative measures of specificity, sensitivity, positive predictive value, and negative predictive value (Wong and Lim, 2011). The WHO criteria were validated using SOFA score (Cecatti et al., 2011), but this approach was criticised as the former were derived from the latter (Nelissen et al., 2013b). Lobat et al. (2013) and Menezes et al. (2015) used the WHO criteria as the gold standard for validation of MNM criteria, but as discussed in chapter 2, the WHO criteria were also criticised for underestimating MNM incidence (Nelissen et al., 2013b; van den Akker et al., 2013; Luexay et al., 2014; Witteveen et al., 2016, 2017).

Thus, we did not calculate specificity, sensitivity, positive predictive value, and negative predictive value for the criteria used in this study because there is no gold standard or universally accepted criteria to be used as reference criteria. Nelissen et al. (2013a) and Halder, Jose and Vijayselvi (2014) evaluated the performance of the criteria by applying them to maternal death cases. Theoretically, MNM and maternal death should be comparable, except for the vital status of MNM. We could not use the same approach due to the relatively low incidence of reported maternal deaths during the study period, and they did not belong to all ICD-MM groups. Also, we did not compare the performance of the criteria with the other existing criteria, as such a comparison was outside the scope of this study, but this might be undertaken in a future study.

As mentioned in the methodology chapter (chapter 3), the criteria were evaluated using a rigorous method. The definition of the individual criteria was based on an internationally accepted definition, and the selected criteria for the majority of severe conditions in this study have been utilised in previous research. Moreover, these criteria were reviewed by national and international experts, and they were tested for their applicability in a pilot study. The identification criteria should not be the main focus of any work using MNM to assess the QoC, rather the main concern is developing context-specific criteria for the identification of MNM. This should be followed by building the capacity of a network of clinician to use the criteria, with commitments to act on the findings to improve the quality of maternity service (WHO, 2004; Knight, 2016). This was the approach used in this study

#### *8.2.2.4. Performance of the criteria*

All reported MNM cases were independently reviewed by the principal researcher and reviewers in the hospital, regional, and national panels to confirm they met the identification criteria. Those cases found not meeting the criteria were excluded. 52.9% (9/17) of the excluded cases were related to severe haemorrhage, mainly not satisfying the criterion of “massive blood transfusion” (five or more units of blood transfusion within the first 24 hours). Using the amount of blood transfused as a criterion is a challenge because of the variation in the threshold for massive blood transfusion between different settings, underestimation of blood loss, and the occurrence of inadequate transfusion for cases with severe haemorrhage.

After further review of all 17 excluded cases of MNM, the researcher found only one case that could potentially be an MNM. The case had four previous caesarean sections and was found to have complete uterine rupture, with the foetus and placenta in the abdominal cavity. There was probably an underestimation of blood loss in this case (estimated as 500-600 ml), and consequently inadequate blood transfusion (two units were given). In future it might be worth including complete uterine rupture as an additional criterion for the identification of MNM.

We assessed whether all pre-set criteria were in fact used. We found the criteria were highly used to identify and report MNM cases. All the stipulated criteria for severe haemorrhage, sepsis, and hypertensive disorders were used. 50.0% or more for those proposed for severe morbidities with obstetric trauma, cardiac conditions, respiratory conditions, SCD, and CNS conditions were also used. Less than 50.0% of the proposed criteria was found for events with AFI, ARF, TTP and complications with anaesthesia, which might be due to the few MNM events reported with these

severe morbidities. Because there was no MNM cases were reported with thyroid crisis, acute fatty liver, suicidal attempts, gastrointestinal conditions, and connective tissue disorders, their corresponding criteria were not used. The high used rate can be considered a reflection of the applicability of the criteria.

The frequency use of clinical criteria was higher than for management and laboratory criteria. Clinical criteria were used to report 87.7% (n = 274) of total MNN events. In previous studies that identified MNM in the Netherlands (Witteveen et al., 2015), Tanzania (Nelissen et al., 2013b), and Malawi (van den Akker et al., 2013), clinical criteria were also predominant. Hence, this study provides further evidence on the applicability of clinical criteria to identify MNM.

### **8.2.3. The incidence of MNM**

The incidence of MNM was 3.4 per 1000 registered women for ANC in Oman (95% CI 1.6;5.2) and 4.0 per 1000 (0.4%) women giving birth (deliveries) in the 23 participating hospitals (95% CI 2.7;5.2). The overlap of the two confidence intervals of the above presented incidence indicates that there is no statistical difference between them, thus the incidence of MNM in the 23 hospitals is representative for the whole country.

As discussed in chapter 2, few studies reported the incidence of MNM, with only two studies from the MENA region (Aldawood, 2011; Mansoor, 2014). However, these two studies focused on MNM admitted in ICU only. Thus, it was difficult to compare their findings with those obtained in this study, which included an entire obstetric population in the study site. This study provides the first time estimate of MNM incidence for Oman and the MENA region.

The reported incidence from LMIC was higher than that estimated for Oman in this study (**Table 8.1**). This difference is most likely due to the differences in the health systems and the study methodologies used, including the difference in the identification criteria. Also, in the majority of these studies, the estimated incidence was based on data from one or two hospitals. In general, and as discussed in chapter 2, comparison of incidence and MNM indicators is challenging, and caution is needed because of the difference in the identifications criteria and study methodologies used.

Despite the difference in case definition and methodology, the incidence of MNM for Oman is in line with most of the reported incidence levels of severe acute morbidity

from high-income countries (**Table 8.1**). The majority of these studies were population-based (Zhanag et al., 2004; Wen et al., 2005; Zwart et al., 2008; Lipkind et al., 2009). This low incidence could be attributed to the significant progress in providing access to maternity services in Oman.

Table 8.1: Comparison of incidence of MNM in Oman with other studies and settings

Author (Year)	Country	Incidence of MNM	Setting	Criteria used
<b>This study</b>	Oman	4.0 per 1000 women giving birth (deliveries)	90% of total yearly national deliveries (23 hospitals)	Disease specific
<b>LMIC countries</b>				
<b>Adeoye, Onayade and Fatusi (2013)</b>	Nigeria	120 per 1,000 deliveries	Two hospitals	Disease specific
<b>Chaudhuri and Nath (2018)</b>	India	4.0% of women admitted during pregnancy, childbirth and puerperium up to 42 days	Single hospital	Organ dysfunction
<b>Kulkarni et al. (2016)</b>	India	42 per 1,000 deliveries	Two hospitals	WHO criteria
<b>Karolinkski et al. (2013)</b>	Argentina	0.8% of all women giving birth	25 public hospitals	Mixed criteria
<b>Moraes et al. (2011)</b>	Brazil	15 per 1,000 deliveries	Two hospitals	Mixed criteria
<b>Simsek et al. (2013)</b>	Turkey	30 per 1,000 deliveries	Single hospital	Disease-specific
<b>High-income countries</b>				
<b>Lipkind et al. (2019)</b>	England	5.0 per 1,000 deliveries	Retrospective cohort using data of delivery hospitalisation between 2008 and 2013 to identify SMM using ICD-code	Disease-specific
<b>Lipkind et al. (2019)</b>	Australia	8.2 per 1,000 deliveries		
<b>Lipkind et al. (2019)</b>	USA	15.6 per 1,000 deliveries		
<b>Zwart et al. (2008)</b>	Netherlands	7.1 per 1,000 deliveries		
<b>Zhang et al. (2004)</b>	Europe	9.5 per 1,000 deliveries	Population-based survey (MOMS-B survey) in nine countries	Disease-specific (pre-eclampsia, PPH and sepsis)
<b>Wen et al. (2005)</b>	Canada	4.4 per 1,000 deliveries	Retrospective cohort using hospital discharge data in Canada between 1991 and 2000.	Disease-specific
<b>Waterstone et al. (2001)</b>	UK	12.0 per 1,000 deliveries	19 maternity units. Data for deliveries from 1997 to 1998	Disease-specific

## **8.2.4. MNM indicators for quality of care**

### *8.2.4.1. Severe maternal outcome ratio*

The SMO ratio is defined as the total number of maternal deaths and MNM per 1,000 live births. The SMO ratio for Oman was 4.3 per 1000 live births (95% CI 3.0;5.5), lower than the overall reported ratio by Souza et al. (2013) of 9.0 per 1,000 live births, in the WHO Multicounty Survey. It concurs with the ratio of 4.7 per 1,000 live births recorded for countries with low MMR (defined as MMR < 20) in the WHO Multicounty Survey.

Focusing on the MENA region, the SMO was also lower than reported by Bashour et al. (2015) of 8.5 in a survey in five MENA countries (Egypt, Lebanon, Palestine and Syria), and by Jabir et al. (2013) of 5.7 per 1000 live births from six public hospitals in Iraq. It was also slightly lower than the recorded ratio of 5.3 per 1000 live births by Jayaratnam et al. (2016) in a single hospital in Australia (**Table 8.2**). However, one of the limitations of comparison of this ratio and all MNM indicators is the difference in the criteria used for identification of MNM itself.

### *8.2.4.2. MNM ratio*

Similar to the SMO ratio, the MNM ratio found in this study of 4.0 (95% CI 2.7;5.2) per 1000 live births was lower than the overall ratio noted by Souza et al. (2013), in the WHO Multicounty Survey of 8.3, and in line with the recorded ratio for countries with low MMR (4.7 per 1,000 live births) in the same survey. The ratio was lower also than the recorded ratio from studies in the MENA region. Comparison with developed countries was limited to the two studies from Australia. The ratio was consistent with the reported ratio of 4.8 per 1,000 live births from Cairns Base Hospital (Jayaratnam et al., 2016), and slightly lower than the one noted in Royal Darwin Hospital (6.0 per 1000 live births (Jayaratnam et al., 2011) (**Table 8.2**).

Table 8.2: Comparison of MNM indicators for Oman with other studies

Author (Year)	Country	SMO ratio per 1,000 live births	MNM ratio per 1,000 live births	MNM: 1MD	MI (%)	Setting	Criteria used
<b>This study</b>	Oman	4.3	4.0	10.3:1	7.4		Disease specific
<b>Ali et al. (2011)</b>	Sudan	-	22.1	-	19.5	Single hospital	Disease specific
<b>Almerie et al. (2010)</b>	Syria	-	32.9	60.1:1	1.7	Single hospital	Disease specific
<b>Bashour et al. (2015)</b>	Egypt, Lebanon, Palestine and Syria	8.5	7.8	11.8:1	7.8	Four hospitals (one from each country)	WHO
<b>El Ghardallou et al. (2016)</b>	Tunisia	6.0	5.9	58:1	1.7	Single hospital	WHO
<b>Ghazivakili (2016)</b>	Iran	5.2	5.0	27.4: 1	3.5	13 hospitals (1 province)	WHO
<b>Ghazal-Aswad et al. (2013)</b>	UAE	-	-	35.6:1	-	4 hospitals (1 province)	Disease specific
<b>Jabir et al. (2013)</b>	Iraq	5.7	5.0	9:1	11.0	6 hospitals	WHO
<b>Jayaratnam et al. (2011)</b>	Australia	-	6.0	-	-	Single hospital	WHO
<b>Jayaratnam et al. (2016)</b>	Australia	5.3	4.8	10.1	-	Single hospital	WHO
<b>Murphy et al. (2009)</b>	Ireland	-	-	79:1	-	3 hospitals	Organ dysfunction
<b>Waterstone et al. (2001)</b>	UK	-	-	118:1	-	19 maternity units within the South East Thames region and 6 from neighbouring region	Disease specific
<b>Souza et al. (2013)</b>	29 countries	9.0	8.3	5.2:1	16.1	357 hospitals	WHO
<b>Souza et al. (2013)</b>	2 countries with low MMR (<20)	4.7	4.7	-	-	13 hospitals in 2 countries	WHO

#### 8.2.4.3. MNM: 1 MD ratio

The MNM: 1 MD ratio was proposed in the WHO MNM approach as a proxy measure for QoC. Higher MNM: 1 MD ratio indicates better QoC. This study noted an MNM: 1MD ratio of 10.3:1 (95% CI 4.6;16.0). This means that for every 10 MNM, it is expected one maternal death occurred. There is no reference range to compare the ratio as an indicator of QoC. From high-income countries only three studies reported MNM: 1MD ratio. Waterstone et al. (2001) reported a ratio of 100: 1 in the UK, and Murphy et al. (2009) recorded a ratio of 79: 1 in Ireland. The observed MNM: 1 MD ratio for Oman was in concurrence with the findings of Jayaratnam et al. (2016) of 10.1: 1 in Cairns Base Hospital, Australia.

The ratio of 10.3:1 (95% CI 4.6;16.0) for Oman needs to be interpreted with caution. The MNM: 1 MD ratio is not suitable to be used as a measurement of QoC in settings with few or no observed maternal deaths. To take into account the hospitals with no MD, this study used a weighted mean in the estimation of the ratio. There were 13 hospitals with no observed maternal deaths, and these were omitted from the estimated mean. Thus, the weighted ratio differs from the crude ratio (12.5:1). Hence, an MNM: 1 MD ratio cannot be used in hospitals with no maternal deaths as a diagnostic tool of QoC. This was a striking observation, as the WHO approach and indicators were primarily proposed to be used in healthcare facilities (WHO, 2011).

Similar observations were noted in Australia. In King Edward Memorial Hospital for Women, Western Australia, the researchers were also not able to use the MNM: 1MD as a tool to assess the QoC as there was no maternal death during the study period (Jayaratnam et al., 2018). Therefore, as Jayaratnam et al. (2016) argued, it is important to interpret the MNM: 1MD ratio within the context of these “near-misses”, and values are not to be taken alone as a reflection of QoC. Therefore, evaluating the QoC provided by in-depth review or standard-based audit, as was the case in this study, provides much better information and is more likely to identify areas of substandard of care than measuring the ratio between MNM and maternal death.

In fact, the interest of looking into MNM as a measure of QoC was proposed and introduced in settings where maternal death is rare. Most of the maternal deaths in these settings are due to non-obstetric complications, with a high case fatality rate. Moreover, the absence of maternal deaths in a healthcare facility does not always mean good QoC, as the facility could refer cases with critical conditions to other healthcare facilities. Even in LMIC countries with a high maternal mortality ratio, caution should be taken when calculating and interpreting the MNM: 1 MD ratio. For

example, consideration must be taken for late presentation of women in critical condition, whereby limited care can be provided at that stage of illness (Jayaratnam et al., 2018). Nevertheless, the MNM:1 MD ratio for Oman (10.3:1) is better than the MNM: 1MD reported in the WHO survey (5.2:1) (Souza et al., 2013). That study also did not report MNM: 1 MD ratio for countries with low MMR, because there were no deaths in these countries during the survey.

There was a wide variation observed in the reported MNM: 1MD ratio from the MENA region, as illustrated in **Table 8.2**. Oman's ratio was similar to that observed by Bashour et al. (2015) of 11.8:1 in Egypt, Palestine, Lebanon and Syria, and by Jabir et al. (2010) of 9:1 in Iraq. Better ratios have been observed in Syria (32.9:1) (Almerie et al., 2010), UAE (35.6:1) (Ghazal-Aswad et al., 2013), and Iran (27.4:1) (Ghazivakili et al., 2016).

Such differences might be explained either by difference in the study design, including the MNM identification use, and/ or the study's context. Almerie et al. (2010) recruited cases retrospectively in a single tertiary care hospital. They described that the majority of MNM arrived in a "critical condition", and a high percentage of maternal deaths in the study setting died before arrival to a tertiary hospital. Such observations might have affected the estimated ratio. Ghazal-Aswad et al. (2013) used both a retrospective and prospective design. Ghazivakili et al. (2016) emphasised that caution needs to be taken in interpreting their findings as a reflection of good quality of care because of the challenges they faced with implementation of the WHO MNM criteria, and the potential impact of the location of the study sites relative to other healthcare facilities, which could affect the morbidity and mortality they observed.

#### *8.2.4.4. Mortality index*

Based on the WHO MNM approach (WHO, 2011), a higher index indicates more women with severe morbidities die, thus indicating relatively worse QoC. The observed MI in this study was 7.4% (95% CI 4.1;10.8). Similar to the MNM: 1MD ratio, it is also difficult to use this indicator as a measurement of QoC in a setting of few or no observed MNM. This estimated index is consistent with that noted by Bashour et al. (2015) of 7.8%, and lower than that reported by Jabir et al. (2010) of 11%, and Ali et al. (2011) of 19.5% in Sudan (**Table 8.2**). However, it is higher than that conveyed by Al Almerie et al. (2010) of 1.7% in a single hospital in Syria.

## **8.2.5. Causes of MNM**

### *8.2.5.1. Pregnancy with abortive outcome*

Causes categorised under the group “pregnancy with abortive outcome” included 5.8% (n = 18) of all MNM events. It was difficult to compare this figure with the reported one in the literature due to the heterogeneity in reporting MNM events related to this group. A few studies recorded all cases of severe morbidity of early pregnancy under one group (Jabir et al., 2013; Oladapo et al., 2016). In Iraq, Jabir et al. (2013) reported a figure of 4.7%, which is line with the 5.8% observed in Oman, while Oladapo et al. (2016) recorded a higher figure of 18.2% in Nigeria. The difference of the findings of this study from the latter can be explained by the difference in the context, definition, and categorisation of cases.

Only 2.9% of MNM events were related to ectopic pregnancy in Oman, lower than the reported figures from the other studies in the MENA region (between 4.4% to 11.3%) (Almerie et al., 2010; Ali et al., 2011; Bashour et al., 2015), which might be due to differences in risk factors. Only 0.6% of MNM identified in Oman were attributed to induced abortion. In general, Oman is a conservative country; abortion is illegal in civil law, and culturally unacceptable unless the mother’s life is in danger, which might explain the low number of abortion cases noted in the study.

### *8.2.5.2. Hypertensive disorders of pregnancy*

The hypertensive disorders of pregnancy group was the leading cause of MNM, accounting for 44.0% of cases, with slight variation between different reviewers. Severe preeclampsia was the most common single cause, contributing to 21.7% (n = 68) of MNM, followed by eclampsia with 19.5% (n = 61). By contrast, other studies in the MENA region reported a higher figure for severe pre-eclampsia (between 46.1 and 63.5%), and a lower figure for eclampsia (between 3.6% and 7.7%) (Almerie et al., 2010; Ghazal-Aswad et al., 2013; Bashour et al., 2015; Ghazivakili et al., 2016). Such differences might be due to the differences in definitions used, or misclassification of cases. It could also be to differences in sample size, as these studies were not population representative (i.e. for all women giving birth), unlike this study.

The incidence of eclampsia observed in this study (0.1% of total deliveries) is lower than the overall incidence recorded in the WHO survey of 0.3%, and lower than the regional incidence (0.2%); 0.1% was reported for Qatar in the same survey, which reflects the country’s close similarities to Oman (Abalso et al., 2014). In fact, the study was able to measure more accurately the frequency of severe outcome of PIH

in general, and eclampsia in particular. Previously, it seems maternal death due to eclampsia and PIH was underestimated, and Oman's figure was challenged when compared with developed countries (Lewis, 2011). The incidence of eclampsia observed in this study was high compared to developed countries (0.2 to 0.6 per 1000 deliveries) (Knight et al., 2007; Zwart et al., 2008; Lipkind et al., 2019).

In these countries, such low rates were achieved by continuous improvement in screening, early detection, and management of PIH and eclampsia, as well as improvement in organisation of care (Knight et al., 2007; Conti-Ramsden et al., 2019). These improvements are based on the lessons learnt from the in-depth review of maternal deaths review and severe maternal morbidity with PIH and eclampsia, like in the case of the UK (Knight et al., 2007; Conti-Ramsden et al., 2019). Conti-Ramsden et al. (2019), based on a review of the UK and other countries' experiences, argue that eradication of maternal deaths due to hypertensive disorders is possible in principle.

In the case of Oman, opportunities for improvement in care were identified in more than 50.0% of MNM events with hypertensive disorders. Also, factors related to healthcare providers were associated with more than 50.0% of events, with recommendations for policymakers and managers to act to strengthen healthcare providers' skills in recognising and managing hypertensive disorders of pregnancy in order to reduce both maternal deaths and severe morbidity from (pre-)eclampsia.

#### *8.2.5.3. Obstetric haemorrhage*

Obstetric haemorrhage was the second most common cause of MNM and was assigned to more than a quarter of the MNM events by reviewers (hospital, regional, national, and expert). Morbidly adherent placenta (placenta accrete, increta, percreta) was recorded in up to 31.5% (n = 23) of the MNM events. The figure of abnormal placentation was anticipated, given the high rate of caesarean sections in Oman, which increased by almost 10% in less than a decade (from 9.7% in 2000 to 19.0% in 2017) (DoH I&S, 2010, 2017), which is higher than the recommended rate by WHO (WHO, 2015c). It was observed that more than half (54.9%, n = 39) of MNM cases with obstetric haemorrhage had undergone a caesarean section in their previous pregnancies, with 19.7% (n = 14) having had three or more previous caesarean sections. More than half of all cases with abnormal placentation (53.6%, n = 15) had two or more caesarean sections, and more than one-third (35.7%, n = 10) had three previous caesarean sections. In high-income countries, abnormal placentation has been considered a leading reason for an increase in severe

haemorrhage and emergency obstetric hysterectomy, which was believed to be due to the increase in caesarean section rates (Knight et al., 2009, 2018; Stivanello et al., 2010; de la Cruz et al., 2015). The review by de la Cruz et al. (2015) concluded that there is a consistent risk of emergency obstetric haemorrhage for women who had a previous or first-time caesarean section, with higher risk with repeat caesarean sections.

Moreover, a rise in caesarean section rate is linked to an increase of severe maternal morbidity in general. Marshall, Fu and Guise (2011) concluded from their systematic review of 21 studies (including 2,282,922 deliveries) that severe maternal morbidity increased with the increase in the number of caesarean sections. Similarly, the WHO Multicounty Survey reported a higher rate of previous caesarean section among women with severe maternal outcome compared to those without SMO (Souza et al., 2013). In this study from Oman, nearly half (45.9%, n = 90) of women with MNM and gave births previously had a previous caesarean section before the index pregnancy. Therefore, Oman needs to be vigilant to safely reduce the rate of caesarean section. Furthermore, with such a high percentage of abnormal placentation, anticipation of and planning for suspected adherent placenta is needed to reduce the severe morbidity associated with repeat caesarean section (Marr, Lennox and McFadyen, 2014; Knight et al., 2018).

Uterine atony contributed to more than a quarter (28.2%, n = 20) of MNM with obstetric haemorrhage. It was difficult to compare this figure with the majority of MNM studies, as the specific causes of postpartum haemorrhage were not reported (Ghazal-Aswad et al., 2012; Jabir et al., 2013, Souza et al., 2013; Bashour et al., 2015). However, Almerie et al. (2010) reported a slightly higher figure of 34.0%, and in Scotland, the figure was much higher at 75.0% (NHS Scotland, 2014). Mawsime and Buchmann (2016) in their systematic review of postpartum haemorrhage found that uterine atony contributed to 35.2% of 684 MNM due to postpartum haemorrhage, which is slightly higher than the figure noted in this study. The difference between studies might be due to the differences in the definition used to defined severe obstetric haemorrhage (such as the amount of estimated blood loss, and number of blood transfusion units given). The percentage of uterine atony also depends on implementation of active management of the third stage of labour. Moreover, uterine atony is a clinical diagnosis, and often is assigned as a cause of haemorrhage by exclusion if no other findings were noted. The figure found in this

study could also reflect the good anticipation and management of uterine atony, but such interpretation should be treated with caution.

#### *8.2.5.4. Pregnancy-related infection*

Only 1.9% (n = 6) of MNM events were attributed to pregnancy-related infection with severe sepsis. This figure was lower than those observed in Iraq (3.1%) (Jabir et al., 2013) and in Iran (3.8%) (Ghazivakili et al., 2016). The overall figure of MNM events with severe sepsis observed in this study was 3.5% (n = 14) of total MNM events (including those related to pregnancy with abortion outcome, and infection due to non-obstetric cause). Surprisingly, Bashour et al. (2015), did not record any MNM with infection in their survey of four hospitals in Egypt, Lebanon, Syria, and Palestine. In the UK, the estimated incidence of severe sepsis is 4.7 per 10,000 maternities. (Acosta et al., 2014). Such variation might be due to the variation in the use of prophylactic antibiotic, or to a true difference in the incidence of severe sepsis.

Variation in the definition was also proposed as an explanation for the difference in the observed figures of sepsis and severity in studies. A recent systematic review showed a wide variety of definitions and criteria used for maternal sepsis, in response to which is posited a new standardised definition for maternal sepsis: “a life-threatening condition resulting from infection during pregnancy, childbirth, post-abortion, or postpartum period” (Bonet et al., 2017, p.10). This was followed by implementing the Global Maternal Sepsis Study (GLOSS) to develop identification criteria for women with severe maternal infection and maternal sepsis (Bonet et al., 2018). In the GLOSS study, 28 predictors were piloted to select among them criteria for identification of maternal and severe sepsis. Half of these predictors were used in defining sepsis and severe sepsis in this study in Oman. Development of standard criteria for severe maternal infection and maternal sepsis can facilitate comparison between different settings in future.

In contrast to the findings in the UK (Acosta et al., 2014), puerperal sepsis was the most common type of severe maternal sepsis in Oman (1.6% of MNM events). This finding necessitates further exploration of risk factors of puerperal sepsis and stringent attention to the infection control procedures in maternity units in general and in the delivery and postnatal wards in specific.

#### 8.2.5.5. Other obstetric complications

The group of other obstetric complications accounted for 5.1% (n = 16) of MNM events. This figure concurred with the reported figure from Iran (5.7%) (Ghazivakili et al., 2016) and lower than the one recorded in Iraq (17.1%) (Jabir et al., 2013). Peripartum cardiomyopathy was the most common attributed specific cause, accounting for 1.9% (n = 6), followed by obstetric embolism with 1.6% (n = 5) of the MNM events. Four events of obstetric embolism were due to pulmonary embolism, and one was due to AFI. During the same period, four deaths were reported with obstetric embolism (three were due to massive PE, and one was due to AFE), given a total of ten cases with eight PE and two AFE. In Oman, obstetric embolism was highly reported as a cause of maternal death, and the figures were challenged as they were higher than expected (Lewis, 2011). In the absence of autopsy for the majority of deaths in Oman, healthcare providers can assign the cause of death to different conditions. Prospective surveillance, including MNM, using agreed criteria and improved diagnostic workup, which could provide a better understanding of the incidence, risk factors, and management (Knight et al., 2010, 2012). PE is preventable in principle, and not all AFE is fatal (Lewis, 2011).

A total of 6.4% (n = 20) of MNM events resulted from obstetric trauma; 1.3% (n = 4) were recorded under the group of other obstetric complications, and 5.1% (n = 16) under obstetric haemorrhage. The trauma ranged from vaginal, perineal, and cervical tears to uterine rupture and injury to other pelvic organs, including sigmoid colon and bladder. Uterine rupture was recorded in 1.3% (n = 4) of MNM, which is lower than the figure reported by Almerie et al. (2010) (2.6%) and by Bashour et al. (2015) (9.9%). However, such comparison could be limited as the definition of uterine rupture was not clear in these studies (i.e. if it included total rupture as well as partial rupture of previous caesarean section).

In developed countries uterine rupture is uncommon, with a recent estimate from the UK of 0.2 per 1,000 maternities (Fitzpatrick et al., 2012). It was difficult to compare the figure recorded in this study with the one from developed countries due to differences in study methodology. We included only cases with a uterine rupture fulfilling the criteria of MNM; therefore, our figures do not reflect the true picture of uterine rupture in Oman *per se*. Further study might be needed to estimate the incidence and risk factors for uterine rupture.

#### *8.2.5.6. Unanticipated complications of management*

Unanticipated complications of management accounted for 3.5% (n = 11) of MNM events, with a variation of the assigned number between different reviewers. Of the 11 MNM events, six were reported by healthcare providers, and five were assigned only by reviewers. This difference could be attributed to the limitation of set criteria under the group of unanticipated complications, as discussed earlier. Complications related to anaesthesia accounted for six events; surprisingly, four of them were labelled as Suxamethonium (succinylcholine) apnoea. Suxamethonium (succinylcholine) apnoea is a rare disorder caused by a deficiency or inactivity of the cholinesterase enzyme (Viby-Mogen and Hane, 1978; Sener et al., 2002). It occurs when a patient has received this muscle relaxant but remains paralysed after the surgery because of the inability to metabolise the drug (Viby-Mogen and Hane, 1978; Sener et al., 2002). Confirming the diagnosis is crucial for two reasons. If the diagnosis is confirmed, the patient needs to be informed to avoid the drug in the future, and the diagnosis needs to be documented in the patient file. Otherwise, other causes of apnoea need to be ruled out and lessons should be learned if they are related to mismanagement before (including pre-anaesthetic check) or during the anaesthesia, especially with such an unexpected number of events.

The other two cases had complications due to cerebral anoxia after general anaesthesia, and cardiac arrest following spinal anaesthesia. Increasing the use of regional anaesthesia and improving anaesthetic practice can reduce severe maternal morbidity related to anaesthesia (Marr, Lennox and McFadyen, 2014).

The complications reported in the other five events were due to fluid overload, life-threatening transfusion reaction after receiving incompatible blood, artificial rupture of membrane causing the cord to prolapse, and severe obstetric haemorrhage. Four MNM events occurred in patients who had surgery and might also be related to the management during the anaesthesia. In three cases this was fluid overload, and one case had a life-threatening transfusion reaction after receiving incompatible blood. The latter event necessitates a review of safety procedures and monitoring of blood transfusion. Up to our knowledge currently, there is no national system for reporting for such incidents. They are recorded as incident reports at the hospital level, but the Department of Blood Services intends to develop a national reporting system. In the UK and other European countries, a national reporting system exists called Serious Hazards of Transfusion (SHOT) (Bolton-Maggs and Cohen, 2013). Incompatible blood transfusions are considered as “Never events” in the UK,

however four events were reported between April 2018 and January 2019 (NHS, 2019).

#### *8.2.5.7. Non-obstetric complications*

Non-obstetric complications were the third most common cause of MNM and accounted for 17.9% (n = 56). Such a high figure is expected with the high prevalence of non-communicable diseases and hereditary blood disorders in Oman (Department of Statistics and Health Information, 2017). Almost half (9.6%, n = 30) of these MNM events were due to SCD. SCD is a common genetic blood disorder in Oman, with a prevalence of 5.8% (Al-Riyami et al., 2001). Previous studies documented its association with a high incidence of maternal and foetal complications (Al Kahtani et al., 2012; Oteng-Ntim et al., 2014). Al-Farsi et al. (2013) examined maternal complications in 68 pregnant women with SCD in a tertiary hospital in Oman. They reported a high rate of hospital admission (96.0%), ICU admission (12.0%), SCD crisis (88.0%), acute chest syndrome (ACS) (20.0%), blood transfusion (90.0%), and infection (25.0%). This study provides additional support to these findings. Among the 56 MNM cases with SCD, the ICU/HDU admission rate was 70.0% (n = 21), and 63.3% (n = 19) developed ACS.

To minimise these complications, comprehensive multidisciplinary care with close monitoring of these women is essential for early identification and interventions (Oteng-Ntim et al., 2014). Preconception care and counselling regarding the risk of complications during pregnancy and planning for future pregnancies is needed. Combining pre-marital screening as a primary prevention to reduce the burden of the disease in the country, with good quality preconception care and care during pregnancy, would be the most effective strategies to reduce severe morbidity and morbidity due to SCD in the country.

Cardiac disease was the second attributed non-obstetric complications to MNM events, with 2.9% (n = 9). Cardiac disease remains the most common cause of maternal deaths in the UK and many other developed countries (Kuklina and Callaghan, 2010; Knight et al., 2014;). Its contribution to maternal deaths and severe morbidity in middle-income countries is also increasing (Campanharo et al., 2015). The proposed reasons for this increase include the increasing rate of obesity and chronic disease among women of reproductive age, with increasing age at birth and survival to adulthood of the majority of children born with congenital disease (Kuklina and Callaghan, 2010; Knight et al., 2014; Hussein, 2017). All of these

factors are currently present in Oman (Al-Mawali, 2015), and might predict an increase of maternal morbidity and mortality from cardiac disease in future.

The remaining non-obstetric complications (respiratory disorders, neurological disorders, and diabetes) are a reflection of the burden of chronic non-communicable diseases in the population and a call for interventions for primary prevention and optimisation of the pre-pregnancy health status of women. It is also an indication for the country to invest in training physicians in obstetric medicine as well as increasing the number of obstetric physicians. To our knowledge, there are currently few obstetricians (less than 10) specialised in obstetric medicine, and they are all in tertiary care hospitals in Muscat.

#### **8.2.6. Comparing the causes of MNM with causes of PLTC and maternal deaths**

The leading causes of MNM were also the main causes of PLTC and maternal deaths, with a slight variation in distribution. The most frequent cause of PLTC was obstetric haemorrhage (51%, n = 723) followed by hypertensive disorders of pregnancy (27.7%, n = 393), then pregnancy with abortive outcome (7.1%, n = 101). Most maternal deaths were due to non-obstetric complications (48.0%, n = 12) followed by other obstetric complications (16.0%, n = 4), hypertensive disorders (12.0%, n = 3), and obstetric haemorrhage (12.0%, n = 3).

Such variation in distribution can be expected given the fact that Oman, like other countries is going through an “obstetric transition”, with an increasing burden of non-obstetric disorders and improved access (almost universal) to maternity services (Souza et al., 2014). With good emergency obstetric care in place in many high-income countries, indirect causes are the main causes of maternal deaths (Kullina and Callaghan, 2010; Knight et al., 2014b). Some conditions, in particular PE and AFE within the group of other obstetric complications, are in themselves acute, life-threatening conditions. Therefore, it is not surprising the proportion of deaths within this group is higher than the proportion of the near-misses and PLTC. However, infection and haemorrhage are not necessarily life-threatening, and can have a better outcome with early recognition and effective management. Also, women with high blood pressure and proteinuria may progress rapidly to MNM status (eclampsia and HELLP) but may be less likely to die than those with non-obstetric and other obstetric complications. This could explain the variation in the MNM: 1 MD ratio (46:1 for hypertensive disorders, compared to 4:1 and 4.7:1 to other obstetric complications and non-obstetric complications) (**Table 5.3**).

### **8.2.7. Assigning underlying cause of MNM**

Good agreement in assigning the ICD-MM group of the underlying cause of MNM was observed between the different review panels. Mgawadere, Unkels and van den Broek (2016) reported poor agreement when assigning the cause of maternal death using ICD-MM between healthcare facility reviewers and an expert panel in Malawi. The good agreement found in our study can be a result of the successful training of healthcare providers and reviewers on assigning underlying cause and use of ICD-MM. In contrast to maternal death, in an MNM event the woman survives, and her full clinical picture is available for reviewers. In the context of Oman, women with severe complications have usually undergone multiple diagnostic laboratory and radiological tests, which might facilitate assigning the appropriate diagnosis.

Despite overall good agreement, some variation was observed in classifying certain specific causes. They are mainly ruptured ectopic pregnancy, peripartum cardiomyopathy, and complications related to anaesthesia. These complications might be confused with other disorders with similar characteristics. For instance, peripartum cardiomyopathy was mixed with pre-existing cardiomyopathy.

### **8.2.8. Contributory conditions to MNM**

The reviewers identified contributory conditions in more than 50.0% of MNM events, with previous caesarean section being the most commonly identified condition. This is followed by medical disorders (including diabetes, anaemia, and other medical disorders), and grand multiparity. These findings are consistent with previous research (Jabir et al., 2013; Pacheco et al., 2014; Cecatti et al., 2015; Leonard et al., 2019). Jabir et al. (2013) noted that previous caesarean sections and anaemia contributed to 55% and 44.5% of MNM respectively. In California, Leonard et al. (2019) demonstrated that previous caesarean section increased the risk of developing severe maternal morbidity by 2.7 times compared to vaginal delivery, and it contributed to 37.0% of cases of severe maternal morbidity.

The rate of caesarean sections is increasing in Oman, as described under obstetric haemorrhage, which might result in an increasing rate of severe maternal morbidity in future if no action is taken. Anaemia and diabetes are a public health concern. In 2017, 26.8% of ANC registered pregnant women were anaemic (<11.0 g/dl), which concurred with the latest population nutrition survey figure of 29.3% (Department of Information and Health Statistics, 2017). Population surveys show a steady increase in the prevalence of diabetes in the Omani population (Al-Lawati et al., 2012), with a prevalence of 12.3% recorded in 2008 (Department of Information and Health

Statistics, 2017). In 2017, from ANC screening, 15% of ANC registered pregnant women were found to be diabetic (including pre-existing diabetes and gestational diabetes). In the same year, despite the success of the family planning programme in reducing fertility rates (from 10.1 to 4.0 (live births per women age 15-49) between 1980 and 2017), 20.3% of ANC registered women were para 5 or more (Department of Information and Health Statistics, 2017).

These findings also emphasise the need to invest more and strengthen pre-conception care to optimise woman's health pre-pregnancy. Also, there is a need for multi-sectoral collaboration to address the growing burden of non-communicable diseases and increase community awareness of family planning.

### **8.2.9. Assessment of quality of care provided to women with MNM**

This study shows an acceptable proportion of MNM events with substandard care. The need for improvement in QoC was identified in almost 56.4% of MNM events. In 19.9% (n = 31) such improvement would have made no difference to the outcome, but in 36.5% (n = 57) improvement in QoC could have made a difference to the outcome. These findings support the finding of the National Maternal Mortality Committee that 50% of maternal deaths are avoidable deaths (Department of Woman and Child Health, 2018). This means that further reduction of maternal deaths and severe maternal morbidity in Oman is possible with improving the quality of care.

The study finding is similar to the findings of other studies on MNM from other high-income countries. Lawton et al. (2014), from their assessment of 98 cases of severe maternal morbidity admitted to ICU/HDU in New Zealand, found that 38.8% were potentially preventable, and in another 36.7% improvement in care were identified which would not have prevented the severe outcome. This finding concordant with previous review by Lawton et al. (2010) in New Zealand. They reviewed 29 cases of severe maternal morbidity admitted in ICU, of which 35% of cases were preventable. Ozimek et al. (2016) in screening 16,323 deliveries in a single medical centre in the USA, identified 150 cases with severe maternal morbidity. They recorded improvement in QoC in 44% (n = 66) of cases. Geller et al. (2004) reviewed the USA maternal morbidities and identified an improvement in QoC in 15 out of 33 cases (45.5%) meeting criteria of MNM. In a national cohort study in the Netherlands, including 371,021 deliveries, 2552 women with severe maternal morbidities were identified, of whom 67 were selected for in-depth review (van Dillen et al., 2010). Substandard care was recorded among 79.1% (n = 53) of them.

Interestingly, these figures of improvement of care are concordant with the recent report of UK CEMM, which noted that improvements in care were identified in 77.0% of reviewed maternal deaths, and in 38.0% of cases such improvement may have made a difference to the outcome (Knight et al., 2018). This similarity of findings could be explained by the similarity of identified factors associated with these severe morbidities. When analysed by cause of MNM, improvements in care were identified in up to 50% of the events of the common causes of MNM (hypertensive disorders of pregnancy, obstetric haemorrhage, and non-obstetric complications). In up to one-third of the events from each group, such improvement might have made a difference to the outcome. This opportunity was slightly higher in obstetric haemorrhage compared to hypertensive disorders of pregnancy and non-obstetric complications, with 37.0% compared to 33.8% and 32.1% (respectively). Perhaps the difference could be explained by the fact that the primary prevention of haemorrhage may be possible, whereas in case of hypertensive disorders and non-obstetric complications secondary prevention is more crucial (Geller et al., 2004). Nevertheless, these figures reinforce the fact that improving care even for women with non-obstetric disorders could make a difference to the outcome.

The opportunity for improvement in QoC for women with haemorrhage found in Oman was higher than the rate reported by Ozimek et al. (2016) in the USA (55.0% versus 38.3%), but the rate observed in New Zealand was 75% (Lawton et al., 2014). In the UK, an enquiry into cases with severe morbidity with major obstetric haemorrhage identified improvement in care in 89.0% of the 34 reviewed cases; in 74% such improvement might have made a difference to the outcome of these cases (Knight et al., 2018).

#### **8.2.10. Comparison of assessment of care by different reviewers**

It was observed that national reviewers and the International Expert Panel were able to identify more opportunities for improvement in QoC compared to hospital and regional review panels. While the International Expert Panel and national reviewers identified areas for improvement in QoC which might have made a difference to the outcome in 36.5% (n = 57) and 34.4% (n = 54) of MNM cases respectively, the hospital and regional reviewers recorded this in only 10.9% (n = 17) and 19.9% (n = 31) of instances, respectively. Similarly, Shah et al. (2016) in the UK found that external reviewers identified areas for improvement in care that could have changed the outcome in 33% of cases of severe morbidity with sepsis, compared to 12% for

local reviewers. In the State of Illinois, external reviewers identified 36.0% more avoidable maternal deaths cases than the local reviewers (Kilpatrick et al., 2010).

It is possible that the “distance” of these reviewers from the reviewed case and the blinded process of the review increased their objectivity. Kilpatrick et al. (2012) argued that the more “distant” the reviewers from the case, the more likely the review is to be objective. The hospital and regional reviewers review the MNM cases from their respective hospitals and governorate, and they might involve or know the medical team that manages the case, which could have affected the objectivity of their review. In reviewing their own cases, the hospital reviewers evaluate management, staff skills and organisation issues in their facilities which could be a challenge for them to be unbiased. Risk of bias is a well-known limitation of facility review (Baltag, Filippi and Bacci,2012; Lawton et al.,2014). Failure of blame might also inhibit the hospital and regional reviewers from ascribing substandard care to their action (Baltag, Filippi and Bacci,2012).

Conversely, the national and international reviewers reviewed anonymised cases and were not involved in the management of the cases they reviewed. Therefore, it is expected they provide an unbiased and objective opinion on the care. For example, Shah et al. (2016) in the UK reported that one of the challenges for local reviewers is the influence of the people involved in the care of the reviewed case and to provide unbiased, constructive feedback to a colleague. On the other hand, the external reviewers viewed their role to provide an unbiased and objective assessment of care.

It also seems the experience of the national reviewers and International Expert Panel could have made a difference to the outcome of the review. Comparing the hospital and regional review panels, national and international reviewers are more senior in their speciality with more experience in audit and review. The international reviewers have previous training and experience in reviewing severe maternal morbidity and maternal deaths in the UK, with the Confidential Enquiry into Maternal Death and Morbidity in the UK. Also, the national reviewers have longer experience in reviewing maternal deaths compared to hospital and regional reviewers.

The hospital and regional reviewers might do not go in-depth in their assessment of care compared to national and external reviewers. Different reports criticised local review for focusing more on reporting incident without in-depth assessment (Macrae and Vincent, 2014; Shah et al. 2014; Macrae, 2016; Cross-Sudworth et al. 2019). In

their assessment of local reviews of maternal deaths and severe maternal morbidity, Shah et al. 2014 and Cross-Sudworth et al. 2019, observed in the majority the quality was lacking, and root cause analysis was not utilised.

Despite these limitations, the local review remains valuable in identifying local needs and factors affecting the provision of care, as was demonstrated in the findings of this study. Both hospital and regional review can be improved by training and continuous evaluation.

### **8.2.11. Factors associated with MNM**

#### *8.2.11.1. Factors related to healthcare team*

This study showed an unacceptable frequency of factors related to the healthcare team (in up to 50% of MNM events). Inappropriate management (prescription of medication, interventions, surgery, etc.) and failure to recognise the seriousness of the severe condition were the leading specific factors. Providers' failure to recognise or misdiagnose the severe morbidity, and as well as mismanagement, were common themes associated with MNM in the literature (Geller et al., 2004; Zwart et al., 2008; Lawton et al., 2010, 2014; Pacheco et al., 2014; Ozimek et al., 2016; Soma-Pillay 2016). The study findings related to healthcare providers are critically important. They emphasise that investment in capacity building of healthcare providers in Oman is a key intervention to reduce maternal morbidity as well as mortality. Geller et al. (2004) demonstrated that the more severe the morbidity, the more likely it is associated with provider-related factors. It is well known that there is more than one point where the healthcare provider can interfere to prevent a cascade of morbidity. Improving healthcare provider skills in interfering earlier in the continuum, can have more impact in preventing the progression of woman's condition along the continuum of morbidity and mortality (Geller et al., 2004; Lawton et al., 2010). For example, the average interval from onset of postpartum haemorrhage to death ranges from 2 to 5.7 hours (Ganatra, Coyji and Rao, 1998; Maine, 1991 cited in Pacagnella et al. 2012). Thus, the earlier the bleeding is recognised, the greater chance of stopping the progression of the condition to death.

Anticipating severe obstetric haemorrhage and planning for appropriate interventions for women with abnormal placentation and those with previous multiple scars can make a significant difference to the outcome. However, it seems the healthcare providers underestimated potential risk for adverse outcomes. An example was demonstrated by managing cases with invasive placenta at secondary care level and leaving cases with multiple C-sections to be operated by junior

obstetricians. The other critical failure that could have made a difference to the outcome of women with obstetric haemorrhage was the delay in recognising severe bleeding, this was an associated factor in more than 20.0% of the cases. Early recognition is crucial for early interventions and prevention of the deterioration of patient condition, as emphasised in the recent UK review of women who survived major obstetric haemorrhage (Knight et al., 2018).

Failure to anticipate severe complications was also evident in the care provided to cases with non-obstetric complications. Delay in referring these women to a higher care facility, failure in involving other specialities in the management and delay in recognising the seriousness of the conditions were the most commonly identified themes in these cases.

Even if the treating healthcare team failed to anticipate complications, they could have recognised them early if they used patient monitoring systems such as obstetric partogram and obstetric early warning system. Despite the availability of such tools in maternity units in Oman, it seems they were not used or used incorrectly. For instance, in more than one-third of MNM with hypertensive disorders of pregnancy, the managing team failed to recognise the seriousness of woman condition.

A striking observation which is worth noting also related to the management of hypertensive disorders of pregnancy. Although magnesium sulphate is the first-line anticonvulsant in women with eclampsia and impending eclampsia (Department of Woman and Child Health, 2016), it was not used in a number of cases. This could reflect the non-availability of the drug or non-adherence to national guidelines. The latter could explain incorrect use of the drug in terms of delay in initiation, incorrect dosage and discontinuation. These findings require further investigation and auditing.

Overall, the study findings related to healthcare providers highlight the need for continuous provider training on recognition and early management of complications. However, a holistic approach is necessary as healthcare provider behaviour can be influenced by many factors, including education/training as well as factors related to the healthcare system.

### 8.2.11.2. *Factors related to women (patients)*

Factors related to the woman herself were identified in up to 34% of MNM events. Patient non-adherence to the prescribed treatment and declining to take medication was the leading factor related to the woman herself. In about one in ten MNM events, the woman did not adhere to the prescribed treatment. Furthermore, in up to 7.7% (n = 12), she declined the medication or procedure.

However, caution needs to be taken to avoid blaming patients based on these findings. Based on recent reviews, there are multiple factors associated with patient compliance and non-adherence to treatment (Jen et al., 2008; Matsui, 2012; Oladejo and Bewley, 2012). These reviews found that factors related to the patient, the medication, the healthcare provider, and the health system all affect patient compliance with treatment. Unfortunately, there are limited studies that focus on pregnant women on this issue, and researchers called for more research to fill this gap (Matsui, 2012; Oladejo and Bewley, 2012).

In general, there is a tendency from local reviewers to focus on patient-related factors as the causes of non-adherence, rather than addressing the behaviours of health care provider and failure of the healthcare system (WHO, 2003). This tendency could be a strategy to protect the managing team as well as healthcare system from criticism and failure to provide good quality care to the woman. It is expected that this tendency of blaming the woman increase if the reviewers were involved in the provision of care to the woman.

Non-adherence could also be a reflection of failure in the patient-healthcare relationship (Oladejo and Bewley, 2012). For example, women might not be involved or consented on key decisions about their management. Furthermore, their previous experience with the quality of care they had received might have influenced their behaviour. Their concern about the safety of the interventions on their baby might not have been addressed. Therefore, to improve adherence, women need to be supported and not be blamed (WHO,2003). They need evidence-based counselling to correct misperception, alleviate fear, and take an informed decision. Therefore, strengthening healthcare providers counselling skills and counselling service in general in maternity units is necessary

Social and economic factors also could influence women's action of non-adherence to treatment or declined procedure. Jin et al. 2008, in their systematic review found that, age, education level, patient income and having social support affect patient compliance to treatment. For example, woman could decline hospital

admission because no one can take care of her children at home. Women's background and place of residence could play a role in her action. Unfortunately exploring these factors was outside the scope of this study. However, secondary analysis of available data could be done in future.

Women's autonomy could also affect their action. In Oman, the law empowers woman to take decision regarding her health and treatment modality. However, there are still in some communities were her husband takes this right when an operative procedure such as c-section is part of her treatment plan.

Delay in seeking care accounted for 12.2% of identified factors related to women. Delay in seeking care is the most complex event to address in obstetric care (Roost et al.2009). The barriers related to health seeking behaviour are wide and including socioeconomic status, education level, recognition of severe systems and previous experience with healthcare system (Thaddeus and Maine, 1994). While many women who develop complications have risk factors, a large proportion of severe obstetric complications occur among women with no previous recognised risk factor (Thaddeus and Maine, 1994; Pacagnella et al.2012). Therefore, it is crucial for women to recognise early the warning signs during pregnancy and to seek care on time.

The barriers from seeking care and factors influencing women non-adherence to treatment are almost similar. It is crucial for health managers and programmers to consider the findings of factors related to woman and address the causes of women's behaviour of non-adherent to treatment and delay in seeking care. Improving health education and counselling services with improving woman's experience of ANC can has a positive impact. However, an in-depth qualitative study might be necessary to explore the influencing factors to take strategic action based on evidence.

#### *8.2.11.3. Factors related to the organisation of care*

Factors related to the organisation of care were the least frequently identified factors but occurred in more than one in four of MNM events (in up to 26.9% of MNM events). Factors related to guidelines and policy, staff, medication, and the referral system were the most commonly identified factors. These findings confirm findings of previous studies that explored factors related to the organisation of care in cases of MNM and maternal deaths (Farquhar et al., 2011; Geller et al., 2014; Lawton et al., 2014; Ozimek et al., 2016).

All reviewer panels agreed that the factors related to guidelines and policy were commonly associated with hypertensive disorders of pregnancy, SCD and morbidly adherent placenta. This finding might explain why these causes were the most frequently attributed causes of MNM. In Oman, the national guidelines for antenatal, childbirth and postpartum care includes policies and management of common disorders and conditions. They are divided into two documents; for primary healthcare facilities and one for secondary healthcare. Each of the tertiary healthcare hospitals have their own guidelines. The guidelines for primary healthcare was last updated in 2016; however, the one for secondary care was updated in 2010. SCD was not addressed in the guidelines for primary health care, and management of adherent placenta is not covered in both documents. Having up-to-date clinical guidelines is crucial for the provision of quality and standardised healthcare for a country like Oman, with multinational health workers from different cultural and training backgrounds.

Despite the remarkable increase in human resources in Oman overall (with 20 doctors and 43.7 nurses per 10,000 populations in 2017, compared to 9 and 26.0 respectively in 1990), staff shortages remain a major health system challenge, particularly physicians (MoH, 2014; DoH I&S, 2017). Currently, there are relatively few highly specialised local (Omani) staff, and most physicians in hospital settings are recruited internationally, with a variety of training and practice backgrounds, and high turnover. For example, in 2017, only 30.0% of physicians in the country were Omani nationals (DoH I&S, 2017). This challenge was recognised in the long-term strategic plan for health, *Health Vision 2050*, and a plan for increasing the number of Omani physicians was endorsed (MoH, 2014).

The MoH policy included Magnesium Sulphate in the list of essential drugs that should be available at all healthcare facilities, and Bakri Balloon device in the list of medical devices to be supplied to all regional hospitals. However, Magnesium Sulphate was the most frequently recorded non-available medication mostly at primary healthcare level. In up to 9.7% of MNM events with obstetric haemorrhage Bakri Balloon device was not available when needed at regional hospitals. These findings indicate a policy-implementation gap in the supply of drugs and medical devices which need to be explored.

Geographical accessibility from women's residence to a healthcare facility that could manage the severe complication were contributing factors in up to 1.9% of MNM events. In these events it seems the accessible healthcare facility was not

equipped to manage severe complication. The women had to have multiple referrals or sometimes by ambulance for long-distance. Time is crucial in managing severe maternal complications to prevent MNM and maternal deaths, especially when these events are related to eclampsia, abruptio placenta and peripartum cardiomyopathy. This finding underscores the need to strengthen the use of air ambulance in an obstetric emergency to avoid any delay, this is a feasible option in Oman.

The referral system is a key pillar in the health system in general. The consequences of failure in the referral process on the outcomes of both maternal and neonatal health cannot be underestimated. Having an effective referral system ensures that mothers receive the right care from the right healthcare providers at the right time and assists in making cost-effective use of healthcare resources (i.e. reduced costs).

Factors related to the organisation of care and those related to healthcare providers are linked. The factors related to the organisation (unavailability of or outdated guidelines or policies, and staff shortage) can contribute to healthcare provider failure. Unavailability of up-to-date guidelines can lead to inappropriate patient management. Policy on staff training affects their skills in managing cases, in particular in emergencies. In most countries, including the UK, regular update training in emergency obstetric care is mandatory, even though staff rarely face emergency conditions (Royal College of Obstetrics and Gynaecologists, 2019). Thus, they need to be consistently updated. Conducting regular maternity obstetric “drills” in hospitals and teamwork, including referral across disciplines, is essential. Furthermore, shortage of staff can increase workload. Research showed that an increase in staff workload increases the likelihood of patient death (Aiken et al., 2014). Therefore, addressing organisational factors can assist in reducing the frequency of provider factors.

#### **8.2.12. Comparison of associated factors identified by different reviewers**

Collectively the national reviewers and international reviewers identified more associated factors with MNM compared to hospital and regional reviewers. Not surprisingly the national and international panels identify more factors related to healthcare team compared to other panels. This could be attributed to the objectivity of the review process and the independence of the national and international panels. The more distance the reviewers from the care given, the more objectively the review process (Killpatrick et al., 2012). This was demonstrated by the steady

increase in the identified healthcare related factors from 31.4% by the hospital reviewers, to 44.2% by the national reviewers and 50.0% by the international reviewers. The hospitals and regional reviewers might have been involved in the management of the MNM events. Such involvement might affect the transparency in examining the quality of care and their ability to recognise failure in their management. Risk of bias is well known limitation of facility review (Baltag, Filippi and Bacci,2012; Lawton et al.,2014). Fear of blame might also inhibit the hospital and regional reviewers from ascribing substandard care to their action (Baltag, Filippi and Bacci,2012). However, if these reviewers failed to step aside from their action and identify the root cause of substandard care, then the opportunity to learn from the review process to improve the quality of care will be missed.

A striking observation which is worth noting is the difference between the review panels in the recorded proportion of MNM events with factors related to women (patients). Surprisingly, hospital reviewers had the lowest figure which was 19.9%, compare to regional reviewers, national reviewers and international reviewers which were 34.0%, 32.1% and 22.4% respectively. It was expected that hospital reviewers to have the highest figure as in general, there is a tendency from local reviewers to blame the woman for the poor outcome. However, for example, hospital reviewers related non-attendance to ANC and delay in seeking care to 1.3% and 1.9% of MNM events respectively, compared to 5.8% and 4.5% for the International Expert Panel. It is expected that the international reviewers will have the lower figure for the factors related to women because of they were not involved in management of the case, thus less chance of bias and fear of blame.

In general, the difference between the findings of reviewers might be related to the how comprehensive and systematic the review was. Also, the ability of the reviewers to analyse the sequences of MNM events and identify the contributing factor. Cross-Sudworth et al. 2019, on their assessment of local review in the UK found only 13% (18/140) of local reviews using the national guidance and utilising root cause analysis. Therefore, large proportion of these local reviews of care were not optimal and produce weak recommendations.

Despite the findings, local review remains valuable in identifying local needs and factors affecting the provision of care, as was also demonstrated in the findings of this study. Hospital review panels identified more factors associated with MNM related to staffing (shortage of staff, and poor access to senior staff) and those related to blood and equipment than other review panels. It is more difficult for

external reviewers, who were making their assessment solely on the basis of the patient medical records to identify these factors. Moreover, local reviewers have more understanding of the context and health system where these severe morbidities occurred compared to external reviewers.

The quality of local review might be improved by capacity building of the reviewers in using root cause analysis or other similar tools during the review. Inviting an external reviewer to participate in the review process might improve the outcome of the review (van den Akker et al.,2011; Baltag, Filippi and Bacci,2012).

### **8.2.13. Lessons learned for future improvement of care**

On reviewing the cases, healthcare providers and managers identify success and failure in the care provided. They should learn and act on the findings, which should be the primary purpose of conducting the review. Ideally, the lessons learned should be based on the identified successes and failures in the care provided to women. In this study, it seems the reviewers based on the lessons they learned on the identified associated factors with MNM. Factors related to the healthcare team were the most commonly identified factors by all reviewers. Therefore, the reviewers identified more lessons for clinical management compared to those for the healthcare system. Factors related policy and guidelines, medication, referral system, and staff were the most commonly identified factors within the group of organisations of care by all reviewers. These were reflected in the recommendations for improving the healthcare system. Inappropriate management, failure in recognition and assessment of condition were the most commonly identified factors related to the healthcare team. Hence, all panels of reviewers considered conducting training in obstetric emergencies as a priority.

Overall, there was a higher similarity in the identified lessons by different reviewers for healthcare system compared to those for clinical management. This could be because the identified factors related to the organisation of care were fewer and more specific compared to those related to clinical management. Secondly, there was a high disagreement between different groups of reviewers in the assessment of the quality of care which is mainly related to clinical management. There was a higher agreement in the assessment of the quality of care and identified associated factors with MNM between the national and international reviewers which were reflected in the higher similarity between the two groups in the identified lessons to be learned.

The variation observed between the different review panels in the distribution of a specific lesson is expected due to the variation in the distribution of specific factors between the reviewers. The international panel reported a higher proportion of MNM events related to guidelines and treating healthcare team compared to country reviewers. Therefore, the panel stressed more on updating/introducing clinical guidelines and conducting obstetric drills compared to country reviewers. Hospital and regional reviewers had a higher frequency of factors related to the availability of staff; hence, they had a higher frequency of lessons calling to ensure an adequate number of staff compared to national and international reviewers.

It could also be that the knowledge, belief and experience of the group of reviewers affected the identification and selection of lesson to be learned that could actually make a difference. Although all reviewers called to update the clinical guidelines and conduct the obstetric drill, the international reviewers recorded these lessons two to three-times than country reviewers. It might be from their experience and belief these are key interventions that can make a difference.

Both country and international reviewers identified important lessons to be learned. However, in formulating specific lessons to be learned for clinical practice, the international reviewers focused more on specific aspects of clinical care and pointed to a broader action in the whole care pathway the woman received. This observation is consistent with the observation by Shah et al. (2016) in the UK between external and local reviewers. Such difference could be attributed to the training and experience of international reviewers compared to country reviewers. Most of the international reviewers have a longer experience in the review of maternal deaths and MNM in the UK and received standard training. In contrast, before the study, there was no standard training for the local reviewers, and there was no national protocol on the review process. Therefore, as mentioned earlier, the quality of country reviewers can be improved by developing a national protocol, training, and continuous evaluation.

It is important to acknowledge that the comparison between the identified lessons by different reviewers is limited. It based on examining the frequency of lessons rather than looking into themes. A more in-depth analysis can be done in future.

Despite the limitation of the hospital and regional review, from our observation and interaction during data collection, they started to act on the findings and make a change before receiving a formal report of the result. For example, in one

governorate, the healthcare providers and managers were able to identify the problem in the supply of magnesium sulphate to the primary healthcare facilities and Bakri Balloon to secondary care. The issue was resolved by local action. It is well known that participating in the review of MNM or maternal deaths is a healthcare intervention (Lewis, 2014). The review highlights the areas requiring action as reported in this study. It enables healthcare providers and managers to learn from the past and act to improve the future (Lewis, 2014).

### **8.3. Study strengths and limitations**

#### **8.3.1. Strengths**

To our knowledge this is the first national study on MNM in Oman as well as in the MENA region. It is also among very few national studies in the world that targeted more than one severe morbidity. The study had a high participation rate, including all the tertiary hospitals, secondary hospitals, district hospitals, and three private hospitals. It captured more than 90.0% of all deliveries across Oman and over a period of 12 months, to account for seasonal variation. To the best of our knowledge this is the first study in the country that included both public and private hospitals. Thus, the results are representative, and the findings can be generalised. Also, compared to previous studies worldwide, this study included healthcare facilities from all levels (primary, secondary, and tertiary).

An additional strength is the robust study design used. It was among the few studies that use a combined survey with an in-depth review of cases. The study used triangulation to confirm the causes of, contributory conditions, associated factors, and assessment of the standard of care by reviewing the cases at four different levels and comparing the findings of these reviews. Thus, there was a high involvement and participation from all healthcare levels, from the hospital to national levels, which was supported by international participation.

The prospective nature of the study allowed overcoming the challenges of incomplete medical records to identify women with severe maternal morbidity correctly.

To the best of our knowledge this is the first study attempting to use ICD-MM classification of maternal deaths in developing identification criteria for MNM and classifying causes of MNM. The study has produced a very precise and detailed list of MNM identification criteria which can be applied in many other settings, in

particular high-income countries. The identification criteria were systematically used throughout the study. There were very few excluded cases, and very few misclassifications of cases.

Another strength of the study worth noting is the involvement of stakeholders at various levels of the country from planning to implementation. The identification criteria and MNM and approach for identification of MNM were shared with input from stakeholders at the national, regional, and hospital levels. Also, reviewers at the three levels were trained and participated in reviewing the identified cases. They participated in identifying the areas for improvements and providing recommendations for future improvement. Thus, the study succeeded in building an MNM surveillance and review system with capacity-building and ownership of local policymakers and clinicians. It demonstrated the feasibility of implementing an MNM surveillance and review system for other countries in the region.

The results of the study were disseminated in an international conference in Oman with the participation of international experts, and other stakeholders from the MENA region and Oman, including clinicians and managers at the national, regional, and hospital levels. An action plan was formulated with input of the participants to act on the study findings (**Annex 22**).

### **8.3.2. Limitations**

Despite adopting several procedures to ensure collection of high-quality data, some limitations need to be considered. With the size of the study and the number of personnel involved at different stages of the study identification, standardisation of the process was a challenging task. However, different procedures were implemented, including training, guidelines, monitoring, and the support of data collectors and reviewers, to minimise variations between different hospitals.

The study included only three private hospitals, which might not represent all private hospitals in Oman; however, the included private hospitals *were* the major hospitals in Oman. Due to the limited capacity of private hospitals, cases with severe morbidities usually end up in public hospitals. The results showed that only two MNM cases were reported from two private hospitals during the 12 months of data collection, and the rest were referred to public hospitals.

Assigning cause of MNM to one group of underlying causes could limit understanding the burden of all causes of severe maternal morbidity, as a woman

could have suffered two severe morbidities. Nevertheless, the study followed the principle of assigning a main cause of maternal death, and we assume any associated morbidity could have been captured as a contributory condition.

The study design did not allow us to explore the women's perspective of care, such as delay in receiving care on arrival. However, in-depth interviews could ideally be conducted outside the healthcare facility to allow women to express their views freely. With this size of the study, conducting interviews would be overwhelming due to the limited resources available, which could negatively impact on the quality of collected data. Also, we could not explore the healthcare providers' perspectives of care, as well as their perceptions of the implementation process of MNM surveillance and review. Initially, we considered a mixed method study, with the addition of a qualitative component to assess the perception and process of change, but this was not feasible given the time and budget. A future study can explore both topics in detail.

For a similar reason, we could not collect data for all delivering women, therefore we could not estimate risks for developing severe maternal outcomes because a reference group without morbidity was not available. However, the focus of this study was on the QoC, and such estimation can be addressed in future research.

Although women with severe morbidity were identified prospectively, completing data collection forms was done after the women's discharge. Thus, some variables related to the characteristics of women had a high missing rate, such as education status, and timing of booking for ANC clinic. As mentioned earlier, estimating risk factors for MNM was not the main focus of the study, and such research can be carried out in the future.

In spite of the effort to capture cases admitted outside the maternity units, the possibility of missing a number of these cases cannot be ruled out. However, it is expected with such severe cases that an obstetrician would be consulted to review the case. Moreover, there is a possibility that some survivors of the MNM event might have died after discharge. However, the data was cross-checked with the National Maternal Deaths Surveillance and was confirmed.

#### **8.4. Summary**

This chapter has summarised the main study findings based on the stated objectives. It discussed and compared these findings with the existing literature, and

highlighted areas that should inform policy and practice in Oman. It also identified areas that need to be address internationally in relation to using MNM as a tool for assessing QoC. The chapter also discussed the strengths and limitations of the study. The next chapter presents the study conclusion and recommendations, based on the findings and discussion.

## 9. Conclusion and Recommendations

### 9.1. Conclusions

Oman has relatively few maternal deaths, and prior to this study the burden of severe maternal morbidity was unknown. This study was able to measure the incidence of MNM and provide a better understanding of causes of and contributory conditions to associated factors and substandard care in MNM. The study succeeded in combining the survey with an in-depth review of identified cases of MNM and synthesised the findings to provide recommendations for future improvement in care. For the first time in MNM research, the study also utilised the ICD-MM classification of maternal deaths to develop identification criteria and to classify the underlying causes of MNM. This approach facilitates the comparison of causes of maternal deaths and MNM.

The incidence of MNM was 4.0 per 1,000 women giving birth, which is lower than the reported incidence in the MENA region, and which falls within the observed incidence of severe maternal morbidity in high-income countries. Similarly, the estimated MNM ratio of 4.0 per 1,000 live births and SMO of 4.3 per 1000 live births were lower than those recorded in the MENA region, and concurred with those observed in high-income countries.

Using the ICD-MM classifications, the most common causes of MNM were hypertensive disorders of pregnancy and obstetric haemorrhage, accounting for more than half of MNM events, both of which are preventable causes. The group of non-obstetric complications, in particular sickle cell disease, was the third most common cause of MNM. The leading causes of MNM were almost similar to the causes of maternal deaths, thus addressing these causes can reduce both maternal mortality and morbidity.

The increasing caesarean section rate in Oman is a major concern. It is the leading contributory condition to MNM, which necessitates urgent action to reduce the rate safely. Non-communicable diseases including anaemia, diabetes, and other medical disorders are also major contributors to MNM. They need to be addressed by multisectoral collaboration, strengthening pre-conception care to optimise women's health, and comprehensive multidisciplinary care for women with these disorders during pregnancy.

The study demonstrated that in settings with low maternal deaths, the use of MNM to mortality ratio and mortality index to assess QoC is limited. Studies using these indicators need to be cautious in interpreting their findings. In-depth review of MNM cases is a better instrument for assessing the standard of care and can provide valuable data on areas that need improvement.

The study showed that opportunities for QoC improvement that can make a difference to the severe outcomes exist in more than one-third of MNM events. Strikingly, the majority of factors associated with MNM are within the scope of the health system and healthcare team and providers. Factors related to treating the care team were associated with up to half of MNM events. These findings strongly indicate a need for strengthening healthcare providers' training, specifically in recognition of severe conditions and provision of appropriate treatment, particularly in hypertensive disorders and obstetric haemorrhage. Ensuring the availability of updated guidelines and policy is another area that needs to be addressed to reduce the number of women with MNM and maternal mortality in Oman. With these findings, a review of MNM should be encouraged at the local and national levels, and the tool should be incorporated in the review of the maternal deaths as an instrument for QoC assessment.

Although there was a high level of agreement between different review panels in assigning the cause of MNM, variation was observed in the assessment of care, identifying the factors associated with MNM and formulating lessons to be learned. Therefore, having national protocol, continuing training and supporting reviewers of both hospital and regional reviewers is needed.

## **9.2. Recommendations for international organisations and researchers**

- Refine the definition of MNM to be in line with the definition of maternal death, as the current definition of MNM does not exclude accidental and incidental causes. Having mutually consistent definitions is important to facilitate comparison of the causes of these two severe maternal outcomes
- Revise the current "WHO near-miss approach for maternal health" for evaluating the quality of care for pregnancy complications (WHO,2011) to be more comprehensive, with in-cooperation of in-depth qualitative review of MNM. The current approach and indicators (MNM to mortality ratio, mortality index, coverage of key interventions) are limited in measuring and identifying

the substandard of care and reasons for the poor quality of care, in particular in setting with few maternal deaths.

- As MNM ratio was used interchangeably with other indicators, studies reporting MNM need to differentiate between rate and ratio and determine if coincidental and accidental causes were included or excluded in measuring MNM indicators to facilitate comparison of the results.
- Use ICD-MM as a framework for the development of identification criteria and causes of MNM with an expansion of the group of unanticipated complications of management in ICD-MM to reflect a wide range of complications that can lead to severe maternal morbidity and mortality. This group in the current version of ICD-MM (WHO, 2012) is limited to complications of anaesthesia.

### **9.3. Recommendations for Oman**

#### **9.3.1. Recommendation for Ministry of Health and other policymakers**

- It is recommended to continue implementing MNM surveillance and review, along with the review of the maternal deaths, and disseminate the findings with all stakeholders, including professional organisations, healthcare providers, women, and the wider public. The study demonstrated that MNM review could provide valuable data that can contribute to further improvement of the quality of maternity care in Oman. In countries where this method is implemented, its usefulness is well documented (Halliday et al., 2013; Knight et 2014; Marr, Lennox and McFadyen, 2014; Vandenberghe et al., 2017; Lazzerini et al., 2018). To avoid the high burden of data collection and review of cases, the findings of this study can be utilised to select the type of conditions for continuing MNM surveillance and for calculation of sample for an in-depth review of cases. The focus might be on the leading causes of MNM, for example, hypertensive disorders of pregnancy, obstetric haemorrhage, and SCD, which constituted more than 85% of underlying causes of MNM. As there was a high level of disagreement between the local review (hospital, regional) and national and expert review in QoC assessment, continuous training and supporting the hospital and regional reviewers of maternal deaths and MNM is necessary.
- The fact that factors related to staff (shortage of staff and poor access to senior staff) were associated with about 10.0% of MNM required a high-level

action to address the need for adequate numbers of staff, especially senior-level staff.

- The factors related to treating healthcare team were associated with around 50% of MNM events. This call for a national policy on staff training that should include mandatory regular training in managing obstetric emergencies.
- It is recommended the current National Guidelines on Antenatal, Childbirth, and Postpartum Care to be updated to include the latest evidence on the management of common obstetric conditions and emergency. They need to be disseminated, updated periodically (e.g. every three years) and their use to be audited. The rationale for this, factors related to guidelines (outdated or unavailability) was associated with 15.0% of MNM events. Most of these events related to the common causes of MNM; hypertensive disorders of pregnancy, SCD and obstetric haemorrhage (abnormal adherent placenta)

### **9.3.2. Recommendations to Regional Director General of Health Affairs, Hospital Director and Director of Primary Health Care**

- Ensure the availability and sustainable supply of life-saving medication and equipment based on the list of essential medication and equipment. For instance, although magnesium sulphate (for the prevention and management of eclampsia) is a life-saving medication, it was not available in five primary healthcare facilities. Similarly, Bakri Balloon (for management of severe obstetric haemorrhage) is included in the list of essential equipment. However, it was not available in two regional hospitals.
- There is an urgent need to conduct a standard-based audit on the use of patient monitoring systems and adherence of healthcare providers to the national guidelines and policies. The rationale for this, the treating healthcare team failed to; i) recognise the seriousness of woman condition in more than 23 % of MNM events, ii) provide appropriate management in around 28.2% of MNM events.
- Ensure multidisciplinary care for women with medical disorders across the entire pathway (including pre-pregnancy, during pregnancy, delivery, and postpartum), with strengthening the pre-existing pre-marital screening to reduce the burden of SCD. Medical disorders accounted to around one-fifth of MNM events, with SCD was the third common underlying cause for all MNM events.

### **9.3.3. Recommendation for Head of Obstetric Departments and Heads of Nursing and Midwifery**

- It is recommended to have a regular training course in obstetric emergency drills in particular for severe obstetric haemorrhage and hypertensive disorders of pregnancy. Obstetric haemorrhage is a medical emergency; however, there was a delay in emergency response in 12.5% of MNM events with obstetric haemorrhage, and inappropriate management was identified in more than 22% of the events. The treating team failed to assess the severity of 24.6% of MNM events with hypertensive disorders of pregnancy and mismanaged 32.2%.
- Review indications for C-section. Undertake an audit and consider stricter criteria for the decision to deliver by this method. More than half of MNM cases with severe obstetric haemorrhage had previous C-section, and almost one-fifth had three or more C-sections.
- In women with previous multiple uterine scars, C-section should be done by an experienced senior obstetrician and all patients with placenta praevia percreta/accreta should be managed at well-equipped tertiary hospitals. Inappropriate management was identified in 22.1% of MNM with obstetric haemorrhage. They were mostly related to inappropriate management of cases of abnormal placentation and cases with multiple c-sections.
- Ensure women can be heard and develop supportive relationships with treating health care team to disclose and discuss their concerns. Such a relationship could improve women's adherence to prescribed treatment as non-adherence was identified in almost 10.0% of MNM events.

### **9.3.4. Recommendations for obstetricians, midwives and family physician**

- Use monitoring systems (e.g. partogram and obstetric early warning system) for early detection of deterioration in patient condition as a failure of the healthcare team to recognise the seriousness of woman's condition was identified in 23.7% of MNM events, and delay or incomplete assessment of the condition was observed in 12.8%.
- Adherence to evidence-based guidelines and protocols in the management of patients, and involving senior staff early in the management of a sick or deteriorating patient are crucial as in 28.4% of MNM events, the women with MNM events received inappropriate management.

- Medical disorders accounted for one-fifth of MNM, thus, it recommended to refer women with medical disorders early in pregnancy to appropriate specialists for the planning of care (antenatal, intrapartum, and postnatal care), and provide multidisciplinary care throughout pregnancy. Conducting a combined obstetric haematology clinic would facilitate coordination and management of patients with SCD.

### **9.3.5. Recommendations for future research**

The findings of this study highlighted knowledge gaps which need to be addressed:

The findings of this study highlighted knowledge gaps which need to be addressed:

- As this is the first study to deploy ICD-MM in MNM research, further investigation is needed to document the experience of healthcare providers and reviewers in using this approach.
- Explore the perceptions of those involved in the implementations of the study, addressing their challenges and support continuing surveillance implementation in future.
- Following incorporating MNN review into the current maternal deaths review, reassessment of incidence of MNM and standards of care is necessary to determine if the tool actually leads to an improvement in QoC.
- The study showed that factors related to healthcare providers were the most frequently identified. Currently, there are several on-job training and continuous professional education activities for healthcare providers in Oman. Assessment of these training and activities is needed. Furthermore, exploring healthcare providers' perceptions of QoC and challenges they face in the provision of quality care can assist in addressing the identified factors.
- Exploring women's perceptions (i.e. patient satisfaction) must be at the heart of the future evaluation of QoC. Documenting the long-term consequences of MNM events on women's lives is another area that needs to be explored. Further research should also focus on understanding the factors affecting women's compliance with treatment during pregnancy.

## **9.4. Summary**

This chapter presented the conclusion of this study, related to achieving the study objectives. It summarises the main study findings regarding the incidence and indicators of MNM, causes of and contributory conditions to MNM, and associated factors. The main findings of the assessments of QoC and areas for improvement have been highlighted, with consequent recommendations for policy and clinical practice (especially for Oman), and directions for future research.

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## **Annexes**

### Annex 1: Summary of studies included in the systematic review

Objective of the study	Setting/ participants included	Deliveries	LB	No. MD	Total no. MNM	Indicators	Other major findings/ remarks
						SMOR per 1000 LB MNMR per 1000 LB MNM: 1MD MI (%) Incidence/ prevalence Other indicators	
Study number/ Author(s), year/ (country, years)/ QA score/ Study type							
<b>Systematic review</b>							
(1) Kay, Kakaire and Osinde, 2011 (various), QA score: Medium (17) Systematic review							
Assess the prevalence/ incidence of MNM, MMR and case fatality ratio	Sub-Saharan Africa (included 6 studies)	-	-	-	-	Prevalence/ Incidence (1.1-8.3%) Case fatality ratio (3.1-37.4%)	Authors argue that case fatality ratio is a reliable indicator of QoC
(2) Pollock, Rose and Dennis, 2010 (various), QA score: High (19) Systematic review							
Determine the incidence and characteristics of pregnant and postpartum women admitted to ICU	Developed and developing countries Pregnant or up to 6 wks. Postpartum admissions to ICU Included 40 eligible studies reporting outcomes for 7,887 women	-	-	-	-	Incidence of ICU admission 0.7-13.5 per 1000 deliveries	Commonest cause for ICU admissions were obstetric causes No difference in the profile of ICU admission in developing compared to developed countries

Objective of the study	Setting/ participants included	Deliveries	LB	No. MD	Total no. MNM	Indicators	Other major findings/ remarks
(3) Tunçalp et al., 2012 (various), QA score: Medium (16) Systematic review							
Review all available studies on MNM	Included 82 studies from 46 countries	-	-	-	-	Prevalence of MNM per criteria used Disease specific: (06-14.98%) Management: (0.04-4.5%) Organ dysfunction: (0.14-2.3%) Mixed criteria: (0.04-4.43%) Based on meta-analysis, the estimate of MNM was 0.42% for the Mantel criteria and 0.039% for emergency obstetric hysterectomy	Ratio and rate used interchangeably

Objective of the study	Setting/ participants included	Deliveries	LB	No. MD	Total no. MNM	Indicators	Other major findings/ remarks
<b>Disease-specific criteria</b>							
(4) Adeoye, Onayade and Fatusi, 2013 (Nigeria, 2006-2007) Facility survey, QA score: Medium (16) Case control study							
Document the incidence, characteristics, determinants and perinatal outcomes of MNM using a three-level conceptual framework	Two tertiary teaching hospitals pregnant women who attended the hospitals during antenatal (3rd trimester), intrapartum or within 42 days after delivery	382	-	-	75	Incidence of MNM: 12% of deliveries Used a three-level conceptual framework to identify factors that affect access and QoC: 60% of MNM experienced phase one or phase two delay Perinatal outcomes: significant associations between MNM and stillbirth (OR 5.4), low birth weight (OR=3.38)	ANC booking status associated with MNM ANC care at tertiary care level is a protective factor of MNM Main causes of MNM: haemorrhage and hypertension disorders Note: Study was not continuous, there was a 6-month interruption. MNM cases were identified only in labour ward.
(5) Adeoye, Onayade and Fatusi, 2015 (Nigeria, 2006-2007) Facility survey, QA score: Medium (11) Mixed method (prospective case control study & in-depth interview)							
Investigate the spectrum of maternal events from uncomplicated pregnancy to SAMM and MNM Explore d factors associated with the occurrence of severe maternal morbidities	Single teaching hospital attended by pregnant women hospital during antenatal (3rd trimester), intrapartum, or within 42 days after delivery (375 women)	-	-	-	75	Perinatal outcome for MNM: Significantly high rate of stillbirth rate (27%), low birth weight (44.4%), and birth asphyxia (22.2%)	Factors related to QoC associated with MNM: Late referral Maternal knowledge of complications Perception about the facilities based on previous experiences Poor accessibility to emergency obstetric care Note: The authors did not mention how many women were interviewed. Articles 4 and 5 are for the same study. Article 4 presented the qualitative part of the study in addition to some findings of the quantitative part.

Objective of the study	Setting/ participants included	Deliveries	LB	No. MD	Total no. MNM	Indicators	Other major findings/ remarks
(6) Ali et al., 2011 (Sudan, 2008-2010) Facility survey, QA score: High (18) Retrospective CSS							
Determine the frequency of MNM events, MI for cause of MNM and compare MNM cases with maternal deaths	Maternity tertiary care hospital/ Women with MNM during pregnancy, childbirth or within 6 wks. of termination of pregnancy	9,578	9,262	40	205	MNMR: 22.1 MI: 19.5% Neonatal outcome in MNM: (stillbirths (23.7%), early neonatal deaths (5.9%))	The highest MI was for infection (22.2%) and lowest for hypertensive disorder (2.4) 23 women had more than one MNM Main causes of MNM: haemorrhage, infection, and hypertensive disorder
(7) Almerie et al., 2010 (Syria, 2006-2007) Facility survey, QA score: High (19) Retrospective CSS							
Identify the frequency and nature of MNM and evaluate standard of care	Teaching referral hospital in the capital city MNM & maternal deaths occurred before or after arrival to hospital during antenatal, intrapartum, or 42 days post termination of pregnancy	28,025	27,350	15	901	MNMM: 32.9 MNM: 1MD: 60.1:1 MI: 1.7 93% of MNM had complications on arrival. Most MNM were referred in critical condition, considered as an indication of weakness in the referral system. Foetal outcomes for MNM: abortions (11%), stillbirths (6%)	The highest MI was for infection (7.4%) and lowest for hypertensive disorder of pregnancy (0.4%) Major cause of MNM was hypertensive disorders The authors found that use of MI is a helpful indicator in assessing effectiveness of treatment in MNM, however the indicator is limited in identifying the reasons behind poor QoC Recommended conducting in-depth review of cases

Objective of the study	Setting/ participants included	Deliveries	LB	No. MD	Total no. MNM	Indicators	Other major findings/ remarks
(8) Baltag, Filippi and Bacci, 2012 (Moldova, 2005-2006) Facility review, QA score: (NA) Case study							
Analysis of the feasibility of introducing MNM audits	3 referral facilities in Moldova	-	-	-	-	-	The article presents the results of an MNM review pilot conducted at the facility where MNM occurred. Included people involved in the care of the woman. Before the review, women are interviewed. Attendance and frequency of MNM review meetings were found good. Range of deficiencies in the QoC and reasons identified during meetings and related actions proposed. Actions more likely to be implemented if related to organisation than staff members
(9) Bhattacharyya, Srivastava and Knight, 2014 (India) Surveillance, criterion-based audit and confidential enquiry, QA score: (NA) Case study							
Describe the development of MNM review for India	-	-	-	-	-	-	A task force was formed. Literature review was conducted to identify methods of implementing MNM review. Experts were consulted. A framework was developed in consultation with stakeholders, including a combined method of criterion-based audit and in-depth review of cases
(10) David et al., 2014 (Mozambique, 2008) Facility survey, QA score: Medium (12) Prospective CSS							
Determine the prevalence of MNM and explore avoidable factors associated with delays in getting appropriate care, aiming to improve obstetric services	5 referral facilities Pregnant women admitted in the labour or gynaecology emergency ward surviving an MNM event and maternal death during pregnancy or puerperium period	-	27,916	71	564	SMOR: 22.7 MNM: 20.2 Case fatality rate (MI): 11.2% Perinatal outcome (30% of MNM had stillbirth). More than one delay found in 63.8%, 3rd delay identified in about 70% of MNM	Main causes of MNM: haemorrhage & eclampsia 1/3 of MNM cases had no ANC care Patient and/ or relative interview was conducted to complement the gap in the medical file and to explore delay in obtaining care. Only 10% of MNM were satisfied with the care they received

Objective of the study	Setting/ participants included	Deliveries	LB	No. MD	Total no. MNM	Indicators	Other major findings/ remarks
(11) Ghazal-Aswad et al., 2013 (UAE, 1988- 2003) Facility survey, QA score: Medium (17) Retrospective and prospective CSS							
Determine the epidemiology of SAMM and explore the impact of ethnicity	4 large public and private hospitals, included all births in facilities. Did not specify GA of included participants	12,270	-	26	926	Prevalence of SAMM: 7.5 per 1,000 deliveries MNM: 1MD 35.6 Perinatal outcome (perinatal death was 4.7% in SAMM). ICU admission: 58.6%	Main cause of SAMM: preeclampsia and haemorrhage
(12) Knight et al., 2014 (UK, 2011-2013) Surveillance and confidential enquiry, QA score: (NA) Case study							
Description of the UK approach of MNM review	Consultant-led obstetric unit	-	-	-	-	-	The UK has a UK Obstetric Surveillance System for MNM, complemented by topic-based Confidential Enquiry into Maternal Morbidity
(13) Naz et al., 2014 (Pakistan, 2012-2013) Facility survey, QA score: Low (9) Retrospective cohort							
Determine the frequency and causes of MNM cases, and compare them with those of maternal deaths	One teaching hospital/ participants unspecified	7,406	7,064	20	71	MNMMR: 10.5 MNM: 1 MD: 3.5:1 % ICU admission, % blood transfusion $\geq$ 3 units, % use of ventilator support, % hysterectomy	Causes of MNM: haemorrhage, HTN, dystocia, sepsis More 50% of MNM were diagnosed with MNM on arrival and 77.4% were not registered for ANC
(14) Rabia et al., 2011 (India, 2008-2009) Facility survey, QA score: Medium (12) Prospective CSS							
Explore the pattern and associated risk factors of SAMM and maternal deaths to develop guideline reduce MNM and maternal deaths	Tertiary care hospital Admitted pregnant or delivered women up to 42 days post-delivery with MNM or maternal death	6,869	NA	27	393	Incidence of SAMM: 57/1000 deliveries MNM: 1MD: 14:11	63% of SAMM were not registered for ANC 24.9% of MNM were referred in critical conditions Patient or relative was interviewed to collect relevant information

Objective of the study	Setting/ participants included	Deliveries	LB	No. MD	Total no. MNM	Indicators	Other major findings/ remarks
(15) Roost et al., 2009 (Bolivia, 2007) Surveillance - data from medical notes, QA score: Medium (16) Prospective CSS							
Explore the frequency and causes of MNM and maternal deaths	Four referral hospitals Admitted women with MNM or maternal deaths occurring before or after arrival to hospitals (did not define GA)	8,136	8,028	15	401	MNMR: 50 MI:3.6% % first delay - decision to seek care highlighted and weak referral as a problem 74% of women who died or those with MNM were in critical condition on arrival to hospital	Defined MNM as "immediately life threatening, pregnancy-related complication that was resolved by chance or by medical care" Main causes of MNM: haemorrhage and hypertensive disorder
(16) Siddiqui, Soomro and Shahih-UI-Hasani, 2012 (Pakistan, 2010) Survey, QA score: Medium (13) Prospective CSS							
Explore the frequency, causes, and outcomes of severe obstetric morbidity	Single public hospital in Karachi/ Obstetric patient (unspecified GA) admitted in obstetric unit	1,508	1,442	19	111	Incidence of SMO: 86.20/1000 deliveries MNMR: 76.96 MNM: 1MD: (5.8:1) % of admission to ICU: % obstetric hysterectomy: 2.8 per 1,000 LB % prolonged ventilation: 10.4 per 1,000 LB, % repeated surgeries: 2.8 per 1,000 LB	Main causes of MNM: haemorrhage, hypertensive disorders and ruptured uterus About 90% of MNM were unregistered for ANC Cases were recruited from obstetric unit only for 5 months. Author called to increase antenatal coverage and emergency obstetrics services
(17) Simsek et al., 2013 (Turkey, 2010-2012) Survey, QA score: Low (9) Retrospective case control							
Explore characteristics of women with MNM to determine the risk factors of maternal death	One tertiary hospital, participants not clearly specified (obstetric patients fulfilling Filippi criteria & maternal deaths, GA not specified)	2,687	-	10	85	MNM rate: 3.05% of total deliveries ICU admission:100%	Rate of maternal deaths was 10.5% MNM cases with severe HELLP syndrome with intracranial haemorrhage, required additional surgical intervention or multiple transfusions at higher risk of death

Objective of the study	Setting/ participants included	Deliveries	LB	No. MD	Total no. MNM	Indicators	Other major findings/ remarks
(18) Tamura et al., 2012 (Sub-Saharan Africa, 2009-2011) Secondary analysis of programme MSF database, QA score: Low (9) Retrospective analysis of routine programme data - MSF							
Determine the proportion of (SAMM) from total deliveries and the pattern of SAMM	Hospitals with MSF project/ women who gave birth at study facilities and develop severe complications not defined	18,675	-	63	6,314	MNM: 1MD: 100:1	Rates of MNM ratio and MNM:MD ratio varied for the included countries, attributed to availability of resources and QoC Data extracted from medical notes
(19) Vandenberghe et al., 2017 Surveillance and criterion-based audit, QA score: Case study							
Described the Belgian Obstetric Surveillance System	Belgian maternity units	-	-	-	-		Belgian Obstetric Surveillance System est. 2011 to monitor severe maternal morbidity and improve QoC by providing recommendations based on results Adapted the UKOSS system
(20) van den Akker et al., 2011 (Malawi, 2007-2009) Facility-based review, QA score: Medium (17) Prospective cohort							
Evaluate the effect of MNM audit by assessing the changes in incidence of maternal mortality and SAMM during the audit period	All health facilities in the Thyolo District Data collected from secondary hospitals Pregnant women and those who delivered up to 42 days postpartum admitted in these facilities	-	-	46	340	MNM: 1MD: 7.4 Case fatality rate: 11.9%	There was a reduction of 3.1 cases of severe maternal complications per 1,000 deliveries Major reduction observed in uterine rupture and obstetric haemorrhage Managers and health providers identified substandard care during audit sessions conducted every 2-3 weeks Recommendations implemented and followed-up during subsequent sessions

Objective of the study	Setting/ participants included	Deliveries	LB	No. MD	Total no. MNM	Indicators	Other major findings/ remarks
<b>Management-based criteria</b>							
(21) Aldawood, 2011 (Saudi Arabia, 1999-2009) Facility survey, QA score: Medium (17) Retrospective cohort							
Determine the incidence, indications, and outcome of obstetric patients admitted to ICU	ICU in tertiary hospital Obstetric patients admitted to ICU, unspecified GA	-	-	75	-	Incidence of ICU admission (0.15% of total deliveries) Mortality of critical ill obstetric patients: 8%	Main causes of ICU admission: pregnancy-induced hypertension, obstetric haemorrhage (obstetric), sepsis due to pneumonia (non-obstetric indication)  Low mortality rate attributed to availability of qualified critical care physicians and obstetricians 24hrs a day, multidisciplinary team care of woman
(22) Chantry et al., 2015 (France, 2006-2009) Population survey, used hospital discharge data, QA score: High (19) Retrospective CSS (National descriptive chart review)							
Determine the rate of pregnancy-related ICU admissions, the characteristics and severity of these cases, and their trends	All ICU in France/ obstetric admission	3,262, 526	-	-	11,824	Rate of pregnancy-related ICU admission: 3.6 per 1,000 deliveries Case fatality rate: 1.3%	Main causes for ICU admission: hypertensive disorders and obstetric haemorrhage  Rate of pregnancy related ICU admission decreased while the severity of cases increased, indicating better selection of cases for ICU admission  Overall case mortality rate remained low, indicating good management
(23) Donati, Senatore and Ronconi, 2012 (Italy, 2004-2005) Population survey, QA score: Medium (17) Retrospective CSS							
Identify MNM among women admitted to ICU or coronary units, explore the causes, and calculate specific maternal morbidity rates	Women aged 15-49 resident in participating regions, with one or more hospitalisation in ICU during pregnancy, childbirth, or within 42 days of termination of pregnancy between 2004-2005	539,382	-	90	1,259	Incidence of ICU admission: 2.0 per 1,000 deliveries MNM: 1MD: 8.5:1	Main causes of MNM: obstetric haemorrhage, DIC and HTN MNM more common among immigrants and previous CS

Objective of the study	Setting/ participants included	Deliveries	LB	No. MD	Total no. MNM	Indicators	Other major findings/ remarks
(24) Gombar, Ahuja and Jafra, 2014 (India, 2007-2012) Facility survey, QA score: Medium (15) Retrospective CSS							
Determine the incidence and risk factors of obstetric patients admitted to ICU with focus on standardised mortality ratio (SMR)	ICU in tertiary teaching hospital/ obstetric admissions (unspecified GA)	21,943	-	47	104	Incidence of obstetric ICU admission: 6.5 per 1000 deliveries Mean ICU stay was 5 days Foetal mortality rate was 21.19% Only 16.34% of women with MNM received ANC	HTN disease was the commonest cause of MNM. Sepsis has a high mortality rate Only 16.34% of MNM received ANC care Time interval between hospital admission and admission to ICU admission was less than 24 hrs, attributed to good QoC
(25) Karolinski et al., 2010 (Argentina and Uruguay, 2005) Survey with criteria-based review, QA score: Medium (16) Prospective CSS descriptive study nested in a cluster randomised clinical trial of behavioural intervention							
Review the use of evidence-based practice in the care of mothers who died or who had severe morbidity	20 public hospitals in Argentina and 4 in Uruguay attended by low- and middle-income populations	NA	NA	28	80	MNMR: 3.4 Case fatality rate 13% Overall use rate of effective interventions was 58% in maternal deaths and SAMM Active management of 3rd stage of labour was used in less than 1/3 of the cases No women with PROM received antibiotics	The study was part of a multicentre intervention to increase the use of evidence-based obstetric practice Used maternal death data of 2003-2005 in calculation
(26) Lawton et al., 2010 (New Zealand, 2005-2007) Facility review, QA score: Medium (13) Retrospective CSS							
Explore the characteristic of pregnancy outcomes and preventability for women with SAMM admitted to ICU	Tertiary hospital women who were pregnant or had delivered within the past 42 days and were admitted to the ICU	-	-	-	29	Preventability of SAMM: (35%) of cases were preventable Provider-related events: 82% of all events System related events: 19%	Preventability was assessed by Geller et al. (2004) preventability model (assessment of care from woman entry to maternity care to discharge) Expert panel assessed cases and assigned preventability score

Objective of the study	Setting/ participants included	Deliveries	LB	No. MD	Total no. MNM	Indicators	Other major findings/ remarks
(27) Lawton et al., 2014 (New Zealand, 2011-2012) Confidential enquiry review, QA score: Medium (17) Retrospective CSS							
Determine potential preventability of women with SAMM admitted to ICU or HDU	Tertiary hospital women who were pregnant or had delivered within the past 42 days and were admitted to the ICU in 4 districts	-	-	-	98	38.8% of SAMM cases were preventable Provider related factors were the most frequently identified factors (delay or failure in diagnosis or recognition of high-risk status (51%); and delay or inappropriate treatment (70%))	Two trained external multidisciplinary panels reviewed identified cases Each case reviewed first by a panel member, then the panel discussed the case and consensus was reached in assessing potential preventability Panel identified themes of substandard care using Geller et al. (2004) preventability model
(28) Mansoor, 2014 (UAE, 2008) Facility survey, QA score: Low (9) Retrospective CSS							
Determine the incidence of SAMM to explore associated factors to develop management pathway	Tertiary hospital obstetric patients admitted to ICU out of 4668 women attended for delivery (unspecified GA)	4,668	-	-	23	Incidence of SAMM: 4.9 per 1,000 deliveries	Main causes of MNM: hypertensive disorders and haemorrhage Commented on weaknesses in the referral system between private and public health sector
(29) Oliveira Neto et al., 2009 (Brazil, 2002-2007) Facility survey, QA score: Medium (12) Retrospective cohort							
Determine factors associated with maternal death among women with severe maternal morbidity	Tertiary teaching hospital Women admitted to ICU (unspecified GA)	14,440	14,418	18	30	ICU admission rate: 46.6 per deliveries MNM: 1 MD: 37.4:1	Strong association between inter-hospital transfer and maternal deaths, suggesting delays in diagnosis, management, and referral Authors found use of MMN: MD for specific morbidity is a useful tool to calculate the actual contribution of each morbidity to maternal mortality

Objective of the study	Setting/ participants included	Deliveries	LB	No. MD	Total no. MNM	Indicators	Other major findings/ remarks
(30) Ozimek et al., 2016 (USA, 2012-2014) Survey with facility review, QA score: High (18) Retrospective cohort study							
Apply newly developed guidelines for identification of women with severe morbidity and determine the incidence of SAMM, and opportunity for improvement in maternity care	Single hospital Women with severe morbidity (unspecified GA)	16,323	-		150	Incidence of severe maternal morbidity: 0.9% of total deliveries Main causes of MNM: haemorrhage (71.3%), hypertensive disorders (10.7%) Opportunities for improvement in care identified in 44% Factors related to health care provider (78.8%), patient (28.8%), system (13.6%)	A multidisciplinary team conducted in-depth review of each case to determine the severe morbidity, opportunity for improvement in QoC, and associated factors  Note: used identification criteria based on those proposed by Centres for Disease Control and Prevention (CDC) using list of specified ICD codes

Objective of the study	Setting/ participants included	Deliveries	LB	No. MD	Total no. MNM	Indicators	Other major findings/ remarks
<b>Organ dysfunction criteria</b>							
(31) Chaudhuri and Nath, 2018 (India, 2013-2014) Survey, QA score: Medium (16) Prospective CSS							
Test the application of a clinical definition of life-threatening complications in pregnancy, and determine the frequency of MNM and mortality due to obstetric complications	Single tertiary hospital Women suffering life-threatening complications during pregnancy, childbirth, or within 42 days post delivery	-	4081	23	177	Incidence of life-threatening complications: 4.5% of admitted women Incidence of MNM: 4.0% of admitted women SMOR: 49, MNNR: 43, MNM: 1MD: 7.7:1	Main causes: hypertensive disorders, ectopic pregnancy and obstetric haemorrhage Used modified Mantel criteria
(32) Marr, Lennox and Mcfadyen, 2014 (Scotland, 2003-2012) Confidential enquiry, QA score: (NA) Case study							
Describe the Scottish Confidential Audit of Severe Maternal Morbidity (SCASMM) and present some of the main results for the period 2003-2012	Consultant-lead obstetric unit in Scotland	-	569,887	-	3,491 women with SMM 4,289, no of SMM events	MNMR: 6.1 per 1,000 births	SCASMM is a monthly surveillance system for SMM using a standard reporting system Cases with obstetric haemorrhage and eclampsia were subjected to in-depth review by an expert panel to assess QoC Feedback report sent for each unit with identified weakness and recommendations Haemorrhage the most common cause of severe morbidity (2003-2012): 77% of all reported causes (4.7 per 1000 births) Decline in reported cases of eclampsia
(33) Murphy et al., 2009 (Ireland, 2004-2005) Facility survey, QA score: Medium (17) Prospective cohort study							
Determine the prevalence and causes of severe maternal morbidity	Three maternity hospitals Women severe complication during pregnancy, childbirth, and up to 42 days post-delivery	45,166	-	2	158	Rate of MNM 3.2per 1,000 maternities MNM: 1MD 79:1 ICU admission: 12%	Main cause of MNM: obstetric haemorrhage Based on the results of the study, the 3 hospitals continued conducting quarterly clinical discussion of MNM and cases reported annually

Objective of the study	Setting/ participants included	Deliveries	LB	No. MD	Total no. MNM	Indicators	Other major findings/ remarks
<b>Mixed criteria</b>							
(34) Amaral et al., 2011 (Brazil, 2005) Population-based surveillance and confidential enquiry, QA score: High (20) Prospective CSS							
Population-based review of adverse perinatal events, including SAMM MNM, MD, perinatal mortality as an intervention to help to improve the surveillance system and QoC	9 maternity units (98% of deliveries) in 1 city/ MNM, MD up to 42 days after delivery foetal death at $\geq 500$ g (or $\geq 22$ wks) of pregnancy and early neonatal death	-	-	4	95	MNMR: 21.2 MNM: 1MD: 23.7 1 Preventability score % of women with identified delay receiving care: 20%, seeking care: 14.5%, delay in reaching care: 4.4%	The cases are discussed anonymously by the Municipal Maternal Mortality Committee who assigned a preventability score for the adverse event Analysing the chain of events that leads to unsuccessful events motivates learning process of the reviewers rather than just focusing on identifying substandard care
(35) Assarag et al., 2015 (Morocco, 2012) Prospective facility-based surveys, QA score: High (21) Mixed method (prospective case control and in-depth interview)							
Assess the incidence, characteristics, and determinants of MNM	3 referral maternity hospitals Women with MNM during pregnancy, childbirth, and up to 42 days post-delivery (aged 18 to 49 years), delivered in the study sites and during the study period	-	-	-	-	MNMR: 12 Causes of delays: Main cause for 1st & 2nd delay: lack of an authority to go to a facility, fear of health facilities & financial resources For 3rd type of delay: several referrals between different levels of facilities until arrival in a facility with can provide the needed care and delay to in providing care after arrival	Main causes of MNM: hypertensive disorders and obstetric haemorrhage High % of MNM did not receive ANC follow-up Authors explored details on the circumstances of care from home to the final healthcare facility was explored. Utilised multiple sources of information (hospital records, reports and interviews of women, conducted in their homes) Concluded QoC should be begin prenatally, and women should be provided with information about their deliveries

Objective of the study	Setting/ participants included	Deliveries	LB	No. MD	Total no. MNM	Indicators	Other major findings/ remarks
(36) Bibi et al., 2012 (Pakistan, 2008-2009) Facility survey, QA score: Low (5) Prospective cross-sectional study							
Assess the nature and risk factors of obstetric morbidities in the postpartum period to improve the existing safe motherhood programme in Pakistan	Tertiary referral public teaching hospital Women who required admission and treatment for various obstetrical reasons during their postpartum period (sample size was 125)	-	-	-	-	Incidence of postpartum obstetric morbidity: 4% of total deliveries	Common causes severe morbidity: PPH, pre-eclampsia and sepsis were the most common causes Morbidity more common among rural and illustrate 70% of MNM had ANC Note: the inclusion criteria were not clear (definition/cut point for the severity of the selected conditions and how many days postpartum). The authors did not define the risk factors investigated
(37) Bouvier-Colle et al., 2012 (25 European countries) Population-based surveys using hospital data, QA score: Medium (16) Secondary analysis of survey							
Assess feasibility of developing routine monitoring of maternal health using indicators of maternal mortality and severe morbidity	Hospitals in the 25 EU countries and Norway Women given birth in the participating countries and had one of the 5 selected morbidity criteria/ maternal deaths	-	8,308, 853	519	-	MNM rate varied widely across the EU: (eclampsia: 0.2-1.6 per 1000 women given births, hysterectomies: 0.2-1.0 per 1,000 women)	16 countries provided data of at least one category, only 3 provided data for all selected categories of SAMM Available data insufficient for monitoring trend over time in Europe Argue that epidemiological studies focusing on specific aspects of SAMM are more informative and can complement routine reporting data (e.g., SCASMM and UKOSS in UK, Lemmon study in the Netherlands, Nordic project (NOSS) or the French severe maternal morbidity model

Objective of the study	Setting/ participants included	Deliveries	LB	No. MD	Total no. MNM	Indicators	Other major findings/ remarks
(38) Cecatti et al., 2015 (Brazil, 2010) Population-based survey based on self-reporting complication (ICU admission, eclampsia, hysterectomy or blood transfusion), QA score: Medium (16) Secondary analysis							
Assess the prevalence of MNM and associated factors among women cared by the public health system in the Amazon and Northeast regions of Brazil	1,252 cities from the Amazon and Midwest region Mothers of children less than 1 year of age, who used the public health system, attended the vaccination campaign, and reside in the selected city	-	-	-	-	MNMR: 31.5	Risk factors to develop MNM: indigenous, women who took > 1 hr to reach the hospital, or refused by full hospital Common reported complications: haemorrhage and infection Main limitations: the design of the main study did not consider calculating prevalence, thus information on women who had a pregnancy within the last year but did not attend the vaccination campaign absent; women with infants who died before 1 year of age excluded
(39) Gorbman et al., 2014 (USA, 2008-2011) Multicentre population surveillance, QA score: High 20 Secondary analysis of the National Institute of Child Health and Human Development Data Maternal-Foetal Medicine Unit Network cohort							
Assess the frequency of severe maternal morbidity, its underlying causes, and develop a scoring system for identifying severe maternal morbidity	25 medical centres across USA Women who delivered in these centres (n = 115,502)	11,150	-	7	332	MNMR: 2.9 per 1,000 births Risk score points for factors	Common causes of MNM: PPH and hypertensive disorders Note: used Geller et al. (2004) scoring system to classify cases of severe maternal morbidity. The scoring system was found useful

Objective of the study	Setting/ participants included	Deliveries	LB	No. MD	Total no. MNM	Indicators	Other major findings/ remarks
(40) Karolinski et al., 2013 (Argentina, 2008-2009) Population survey, QA score: Medium (17) Prospective CSS							
Determine the incidence and cause of severe maternal morbidity and maternal deaths, and the use of effective interventions	25 hospitals Women giving birth in participating facilities having MNM or MD during pregnancy, childbirth, or within 42 days post termination of pregnancy (65,033)	-	65,033	34	518	Incidence of MNM: 0.8% of all women giving birth in participating facilities during 1 yr MNM: 1MD: 15:1 Case fatality rate: 6.2% Use rate of known effective interventions was 52.3% Specific use rate was calculated for administration of Mg SO <sub>4</sub> (52.3%), prophylactic antibiotic (58.1%), and management of miscarriage and abortion using vacuum aspiration (4.6)	Severe main causes of severe morbidity: complications due to abortion, obstetric haemorrhage, and hypertensive disorders Note: Private hospitals & small maternity units were not included. Author called to develop a surveillance system for severe morbidity
(41) Lutomski, Greene and Byme, 2012 (Ireland, 2005-2009) Population survey, QA score: Medium (14) Retrospective cohort study							
Estimate the population-based rates of severe maternal morbidity during childbirth hospitalities and associated characteristics	Irish hospital discharge database - retrospective cohort study of 330,955 cases of women admitted to hospital due to childbirth in Ireland	333,576	331,522	4	4,438	Incidence of SAMM: 1.3 cases per 100 deliveries Rate of severe morbidity was 1.34% of childbirth hospitalisation	The rate increased from 1.3 to 1.6 cases per 100 deliveries between 2005-2009 Mixed criteria (disease and interventions) using ICD-10
(42) Moraes et al., 2011 (Brazil, 2009-2010) Facility-based survey, QA score: Medium (14) Prospective cohort							
Determine the incidence of and main causes of severe maternal morbidity	Two referral hospitals Women admitted with complications during antenatal, intrapartum, and up to 42 days postpartum	8,493	2		127	MNM rate: 15 per 1000 deliveries	HTN and haemorrhage as causes of SMM attributed to low QoC Majority of SMM admitted in critical conditions and all deaths occurred outside the high-risk maternity hospitals, attributed to weak referral system MD zero in study sites and 11 in city

Objective of the study	Setting/ participants included	Deliveries	LB	No. MD	Total no. MNM	Indicators	Other major findings/ remarks
(43) Reid and Creanga, 2018 (USA, 2011-2015) Hospital based survey (one state), QA score: High (20) Retrospective CSS							
Examine hospital characteristics and quality metrics associated with severe maternal morbidity	Used hospital discharge data in State of Maryland using discharge record for 364,113 women who had delivery	364,113	-	-	7,171	Rate of severe maternal morbidity: 197 per 10,000 deliveries	Hospital with low patient stratification scores and low QoC score had higher rates of severe maternal morbidities Note: Used ICD code to define severe maternal morbidity
(44) van Dillan et al., 2010 (The Netherlands, 2004-2006) Surveillance and confidential enquiry, QA score: Medium (14) Prospective audit, part of national prospective cohort study							
Describe the panel audit and identify substandard care in selected women from a national cohort study into SAMM	All pregnant women in Netherlands 8 audit meetings throughout Netherlands 2.6% of identified SAMM cases assessed	-	358,874	-	2,552	MNM ratio: 7.1 per 1000 births % of substandard care Incidence of substandard care: 79% (53/67) Common identified associated factors: Delay in treatment after diagnosis: 20.9% Delay in recognition of symptoms and signs: 14.8% Health system related factors: 17.7%	A panel meeting is conducted to assess the anonymised cases During the meeting findings were discussed for substandard care and associated factors

Objective of the study	Setting/ participants included	Deliveries	LB	No. MD	Total no. MNM	Indicators	Other major findings/ remarks
<b>WHO criteria</b>							
(45) Abha, Chandrashekhar and Sonal, 2016 (India, 2013-2015) Facility survey, QA score: Low (8) Prospective CSS							
Audit MNM cases and the pathways that lead to occurrence of severe maternal morbidity and death	Single tertiary hospital Admitted women fulfilling WHO criteria for MNM (unspecified GA)	-	13,859	102	211	MNMR ratio:15.18 MNM: 1MD: 2:1 MI: 32.58% Delay identified in 68.88% of cases (Type I, 44.07%; Type II, 36.01%; Type III, 19.9%)	Common causes of MNM: hypertensive disorders and obstetric haemorrhage
(46) Ashma, Gehanath and Ganesh, 2013 (Nepal, 2012) Facility survey, QA score: Medium (14) Prospective CSS							
Explore the frequency and the causes of MNM events & analyse the MNM morbidities among pregnant women	9 tertiary facilities Women admitted to health facilities	-	41,676	26	157	SMOR: 4.4 MNMR: 3.8 MNM: 1MD: 6:1 MI: 0.1 Coverage of critical interventions use:60% of MNM cases had critical interventions within 12 hours of arrival ICU admission: 54% Time to intervention and referral process: delay in referring cases to higher care level; 60% of cases had organ failure on arrival at healthcare facility	Main cause of MNM: obstetric haemorrhage Main contributory conditions: anaemia The authors called to strengthen the QoC at lower level healthcare facilities, as more than 50% of cases were referred with organ failure High coverage of key interventions with high MNM: 1MD ratio indicate delay in receiving these interventions

Objective of the study	Setting/ participants included	Deliveries	LB	No. MD	Total no. MNM	Indicators	Other major findings/ remarks
(47) Bacci et al., 2018 (Armenia, Georgia, Latvia, Moldova and Uzbekistan) Facility based review, QA score: High (19) Retrospective CSS							
Evaluating the quality of the MNM case review implementation in selected countries within WHO European Region	23 maternity units	-	-	-	-	-	<p>Facility review of MNM was implemented in countries within WHO European Regions.</p> <p>Staff involved in the management of the case discussed care provided against national guidelines and standards</p> <p>Scoring system used to evaluate performance of healthcare facilities in conducting MNM review</p> <p>Quality of review cycle implementation heterogeneous between countries and facilities</p> <p>Steps related to formulating and implementing recommendations as well as disseminating the results poorly implemented</p>
(48) Bakshi et al., 2015 (India, data collection period unspecified) Facility survey, QA score: complemented by patient and / or relative interview, QA score: Low (6) Prospective CSS							
Estimate the prevalence and indicators of PLTC and MNM	2 PHC facilities, 1 Community Health Care facility, and 1 tertiary care facility  All women during pregnancy, labour or postpartum up to 42 days	-	688	10	51	SMOR: 88.7 MNM: 1MD: 5.1 MI: 16.4%	<p>Sampling and data collection process not described in detail</p> <p>Results not presented clearly</p>

Objective of the study	Setting/ participants included	Deliveries	LB	No. MD	Total no. MNM	Indicators	Other major findings/ remarks
(49) Bashour et al., 2015 (Egypt, Lebanon, Palestine, and Syria, 2011) Facility-based survey with criteria-based audit, QA score: High (18) Primary- prospective CSS							
Explore the prevalence, characteristics, and management of MNM cases	4 referral teaching hospitals All women giving birth at those hospitals or referred during the data collection period, and all those who had SMO irrespective of GA, up to 7 days postpartum	-	9,063	6	71	SMOR: 8.5 MNMR: 7.8 MNM: 1MD (11.8:1) MI: 7.8% % of coverage of selected key interventions: high coverage of key interventions (MI high)	PPH was main cause of SMO Recommended in-depth investigation to examine delay in interventions as there was high coverage of key interventions, but MI was high
(50) Benimana, Small and Rulisa, 2018 (Rwanda, 2015) Survey with facility review, QA score: Moderate (17) Retrospective CSS							
Explore the causes and preventability of MNM and mortalities	Single tertiary referral hospital Women who experienced MNM or deaths at the time of admission or during their hospitalisation during pregnancy, childbirth, or within 42 days of termination of pregnancy	-	-	-	-	65% of MNM and 10% of MD were preventable Delays identified in facility level (healthcare provider) delay: 63.5% of preventable MNM System level (supply) delay: 5.8% of preventable MNM Delay in seeking care: 22.3% of MNM MD delay in arrival: 9.1% of MNM and MD	Total identified and reviewed MD and MNM: 121 Main causes of MNM: sepsis, PPH, eclampsia Used modified WHO criteria Review committee including staff involved in the care of the woman reviewed the case file to assign diagnosis and preventability using three-delay model
(51) Bolnga et al., 2017 (Papua New Guinea, 2014-2016) Facility survey, QA score: Medium (13) Prospective CSS							
To estimate the MNMR, MI, and associated maternal indicators	Single referral hospital Pregnant women attended the hospital and fulfilled the WHO definition for MNM	6,232	6,019	10	153	SMOR: 27.1 MNMR: 25.4 MNM: 1MD: 15.3:1 MI: 6.8%	High proportion of MNM were not registered for ANC

Objective of the study	Setting/ participants included	Deliveries	LB	No. MD	Total no. MNM	Indicators	Other major findings/ remarks
(52) Cecatti et al., 2016 (Brazil, 2009-2010) National surveillance, QA score: High (21) Prospective CCS							
Identify cases of MNM and explore the feasibility of using WHO criteria and indicators for identifying women at risk of severe maternal outcome	27 referral maternity hospitals from all regions with at least 1000 LB per year All women admitted to the facilities fulfilling the WHO criteria for PLTC and MNM	82,388	82,144	140	770	SMOR: 11.08 MNMR: 9.4 MNM: 1MD: 5.5:1 MI:15.40% Delays in care identified in 68.4% of MNM cases and 84.1% of maternal deaths	Main causes of MNM: hTN and haemorrhage Argue that severe maternal morbidity occurs approximately at the same rates everywhere, irrespective of the level of income or development, therefore it is more important is to understand when and how they occurred and how they were managed, not just focusing on measuring prevalence only
(53) De Mucio et al., 2016 (8 Latin America countries, 2013) Facility survey, QA score: Medium (15) Prospective CSS							
Evaluate the performance of a systematised form to identify SMO and intervention received	11 hospitals	6,225 (births)	-	2	37	SMO: 12.9 MNMR: 12.3 MNM: 1MD: 19:1 MI: 5.1%	Reported on using standardised form with MNM criteria and list of causes and key interventions for identifying cases with SMO for auditing QoC, implemented for one-month Cases of abortion excluded
(54) Dias et al., 2014 (Brazil, 2011-2012) National survey, QA score: Medium (14) Prospective CSS							
Estimate the incidence of MNM and describe the occurrence of MNM by reason for hospitalisation and place of admission using WHO criteria and indicators	National (266 hospitals with ≥ 500 deliveries sampled from all states)	-	2,325, 394	684	243	MNMR: 10.2 MNM: 1MD: 30.8:1	MNM ratio higher in capital city hospitals Did not include cases of abortion, complications occurring postpartum after hospital discharge, or childbirth at home, or in hospitals with fewer than 500 deliveries per year

Objective of the study	Setting/ participants included	Deliveries	LB	No. MD	Total no. MNM	Indicators	Other major findings/ remarks
(55) El Ghardallou, et al., 2016 (Tunisia 2010) Facility survey, QA score: Low (9) Retrospective CSS							
Explore the frequency and nature of the MNM events and evaluate QoC using WHO indicators	Tertiary referral hospital Women with life-threatening conditions during pregnancy, childbirth, or within 42 days of termination of pregnancy	9,957	9,980	1	58	SMOR: 5.96 MNMR: 5.86 MI: 1.7% MNM: 1MD: 58:1 ICU admission: 72.4%	Main causes of MNM: haemorrhage and hypertensive disorders
(56) Ewnetu Firdawek et al., 2017 (Ethiopia, 2015-2016) Facility survey, QA score: Medium (16) Prospective CSS							
Determine the incidence and causes of MNM	5 referral tertiary hospitals Women admitted to the participating hospitals during pregnancy, childbirth, or within 42 days of termination of pregnancy, experiencing MNM event	-	29,697	-	238	MNMR: 8.0 68.5% of MNM occurred before arrival to hospital, indicating constrains or poor access to healthcare	Main causes of MNM: hypertensive disorder, obstetric haemorrhage Major contributory condition: anaemia
(57) Galvao et al., 2014 (Brazil, 2011-2012) Facility survey, QA score: Medium (14) Prospective CSS with a nested case control component							
Examine the prevalence of SAMM and MNM and their associated factors	2 referral maternity hospitals Women in pregnancy, childbirth, or within 42 days of puerperium, irrespective of the duration and pregnancy condition	16,243	-	17	1,102 SAMM, 77 NM	SMOR: 5.8 MNMR: 4.7 MNM: 1MD: 4.5 MI: 18%	Described SAMM cases as less serious (1102) preceding MNM (77) situations in severity

Objective of the study	Setting/ participants included	Deliveries	LB	No. MD	Total no. MNM	Indicators	Other major findings/ remarks
(58) Ghazivakili et al., 2016 (Iran, 2012) Facility survey, QA score: High (18) Prospective CSS							
Estimate the incidence of, characteristics of, and care provided to MNM	13 public and private hospital admitted pregnant women up to 7 days postpartum Excluded those with abortion	38,715	38,663	7	192	SMOR: 5.2 MNMR: 5.0 MNM: 1MD: 27.4:1 MI: 3.5% SMO12 mortality index: 3.5% ICU admission rate for women with SMO: 72.7%	Main cause of MNM: hypertensive disorders Reported challenges with using the WHO criteria – underestimated incidence of MNM and MNM indicators
(59) Goldenberg et al., 2017 (Democratic Republic of the Congo, Guatemala, Belagavi and Nagpur (India), Kenya, Pakistan, and Zambia, 2014-2016) Facility survey, QA score: Medium (17) Prospective CSS							
Describe the Global Network MNM and Maternal Mortality System	Different levels of health care facilities Women during pregnancy, childbirth or within 42 days of termination of pregnancy (122,707 women screened)	-	-	187	4866	Overall incidence of MNM: 4.0% of all screened women MNM incidence varies from site to site MNM:1 MD: 26:1	Network part of Global Network Maternal and Newborn Health (MNH) Registry in seven countries that modified WHO criteria to screen for MNN All pregnant women living in defined catchment area of the study sites were enrolled and screened for eligibility Eligible women further screened for MNM event

Objective of the study	Setting/ participants included	Deliveries	LB	No. MD	Total no. MNM	Indicators	Other major findings/ remarks
(60) Haddad et al., 2014 (Brazil, 2009-2010) National surveillance with criteria-based audit, QA score: Medium (16) Prospective CSS							
Assessing QoC of women with severe maternal morbidity and identifying associated factors	27 referral facilities Women admitted to participating units for delivery or any pregnancy-related issue	82,388	82,144	140	770	SMOR: 11.4 in facilities with adequate QoC & 10.6 in facilities with non-adequate QoC MNM: 1MD: 10: 1 in facilities with adequate care & 8.4: 1 in facilities with inadequate care Access to care: % of admission to ICU and % of coverage of key interventions	Used MSI and SMR for assessment of performance of healthcare facilities Main factors associated with inadequate performance: geographic difficulty in accessing health services, delays related to medical QoC, absence of blood derivatives, communication problems between health services MSI less precise to be used for populations with a small no. SMO cases. More useful measure for population receiving care, and not for healthcare facilities that provide care Note: Cecatti et al. (2015) and Haddad et al. (2014) used data from the Brazilian Network for Severe Maternal Morbidity, thus the No. total deliveries, LB, MNM, and MD are the same
(61) Herklots et al., 2017 (Zanzibar, 2016) Survey, QA score: High (19) Retrospective CSS							
Explore the impact of in-hospital care on severe maternal morbidity using WHO's MNM approach	Single tertiary hospital Women with PLTC or SMO fulfilling the WHO criteria during pregnancy, childbirth, or within 42 days after termination of pregnancy	4527	4125	28	37	SMOR: 16 MNMR: 9 MNM: 1MD: 1.3:1 MI:43%, Admission to ICU: 56.8% % coverage of key interventions Hospital access indicators: SMO 12hrs: 65% MI SMO 12 (45%) In-hospital MI: 39%	Maternal severity score: 2.66 Mean maternal severity index: 7.32 Standardised mortality ratio: 6.03 Main causes of MNM: PPH and hypertensive disorders of pregnancy Used modified WHO criteria. Authors found high coverage of essential interventions not reflecting the QoC

Objective of the study	Setting/ participants included	Deliveries	LB	No. MD	Total no. MNM	Indicators	Other major findings/ remarks
(62) Iwuh, Fawcus and Schoeman, 2018 (South Africa, 2014-2015) Facility survey, QA score: Low (9) Primary- retrospective CSS							
Estimate the MNM ratio, MMR MI, and explore demographic characteristics, clinical factors, and avoidable factors associated with MNM	2 secondary and 1 tertiary hospital  Did not specify GA or age of recruited participants	19,524	19,222	13	112	SMOR: 6.5 MNMR: 5.83 MNM: 1 MD: 8.6:1 MI:10.4% Factors associated with MNM: Lack of antenatal clinic attendance: 11.6% Inter-facility transport problems: 6.3% Healthcare provider-related factors (PHC: 25.9%, secondary level 38.2%, tertiary level 7.1%)	Main causes of MNM: hypertension, obstetric haemorrhage, and pregnancy-related sepsis  Health care provider-related factors were mostly identified at secondary hospital level
(63) Jabir et al., 2013 (Iraq, 2010) Facility survey, QA score: with criteria-based audit, QA score: Medium (17) Prospective CSS							
Examine characteristics and QoC provided to women with severe complications	6 public hospitals with > 1000 deliveries per year  Women with severe complications during pregnancy, childbirth, or 7 days postpartum	-	25,472	16	129	SMOR: 5.69 MNNR:5.1 MNM: 1MD: 9:1 MI%: 11.03 SMO12 MI: 11.2% Intrahospital MI: 11.1% Perinatal deaths: 43.8% ICU admission rate: 0.28% % of use of key interventions	2/3 of cases had SMO within 12 hours of hospital stay without referral, suggesting delay in referral/ seeking care  Delay in performing laparotomy for ruptured uterus: 17.24%
(64) Jayaratnam et al., 2011 (Australia, 2009-2010) Facility survey, QA score: Medium (14) Prospective CSS							
Assess severe maternal morbidity  To define women with MNM to develop a tool for assessment of obstetric care	Referral hospital  All Women giving birth or admitted antenatally	-	-	-	-	SMOR: 7 MNMR: 6	Common causes of MNM: PPH and pre-eclampsia  Australia has an obstetric surveillance system on rare disease. The study attempted to introduce a surveillance system for MNM

Objective of the study	Setting/ participants included	Deliveries	LB	No. MD	Total no. MNM	Indicators	Other major findings/ remarks
(65) Jayaratnam et al., 2016 (Australia, 2014-2015) Facility survey, QA score: Medium (16) Prospective CSS							
Estimate the rate of MNM and the determine the applicability of WHO MNM approach as a tool for data collection	Single referral hospital All women admitted during pregnancy, childbirth, or up to 42 days of termination of pregnancy	-	2080	1	10	SMOR: 5.3 MNMR: 4.8 MNM: 1MD: 10:1 SMO ICU admission: 90%	Common cause of MNM: PPH Author emphasised that low MNM: 1MD is unexpected for the high resource setting, and should be interrupted with caution as an indicator of poor QoC
(66) Jayaratnam et al., 2018 (Australia, (2014-2015) Facility survey, QA score: Prospective CSS							
Estimate the rate of MNM, aetiology of MNM, and the applicability of WHO MNM approach	Single referral hospital All women admitted during pregnancy, childbirth, or up to 42 days of termination of pregnancy	-	2773	0	19	MNMR: 7	6 months of data collection Researchers were not able use MNM: 1MD and MI indicators for assessment of QoC because of no observed maternal deaths
(67) Kalisa et al., 2016 (Rwanda, 2013-2014) Survey, QA score: High (20) Prospective cohort study							
Explore MNM characteristics and examine process indicators related to QoC using MNM approach	1 referral hospital Women admitted for delivery or pregnancy-related complications, sustained SAMM during pregnancy, childbirth, or up to 42 days postpartum	3979	3994	13	86	SMOR: 24.8 MNMR: 21.5 MNM: 1MD: 7:1 MI: 13.1% % of coverage of key interventions: (Mg sulphate, oxytocin and antibiotic). Admission of SMO to ICU: 28.3%	Common cause of MNM: hypertensive and obstetric haemorrhage Sepsis had highest MI Suboptimal administration of oxytocin (74.4%) to women with severe haemorrhage and parental antibiotic (47.4%) for sepsis. Used Modified WHO criteria

Objective of the study	Setting/ participants included	Deliveries	LB	No. MD	Total no. MNM	Indicators	Other major findings/ remarks
(68) Kiruja et al., 2017 (Somaliland, 2015) Survey, QA score: High (20) Prospective CSS							
Examine the frequency and causes of MNM and the referral chain for women to access skilled birth attendance	Single referral hospital Women pregnant, in labour, or who delivered or aborted within 42 days prior to arriving at the facility	1,385	1,355	18	120	MNMR: 88.6 MNM: 1MD: 6.7:1 MNM on arrival: 74.2%	Main causes of MNM: severe PPH, severe pre-eclampsia, sepsis Reasons for bypassing the antenatal care facility to the referral facility: Lack of confidence with the service provided in the ANC (36%) Lack of financial ability to pay for ANC (43.7%) Lack of time to visit ANC (20.3%) Reasons for late referral: Lack of knowledge of danger signs and where to seek care (46.4%) Poor communication and lack of organized transportation system between ANC facility and hospital (53.6%) 5-month pilot study Women interviewed
(69) Kulkarni et al., 2016 (India, 2012-2014) Facility survey, QA score: Medium (16) Prospective CSS							
Determine the incidence of MNM and examine MNM events	2 tertiary hospitals Women with MNM occurring between conception and 42 days post-delivery	15,234	14,508	94	877	MNM: 4.2% of total deliveries MNM events per LB: 3.6% 884 near-miss obstetric events out of 19,176 obstetric admissions (4.6%) MI (MNM events): 0.096	Common associated factors with MNM events Before admission: unavailability of treatment at lower health care level (68.2%), financial problem (23.9%), transportation problem (20.8%). During admission: unavailability of laboratory tests (16.6%), unavailability of drugs (12.9%), unavailability of blood transfusion (5.0%)  Note: the authors used the MNM event instead of number of women with MNM to calculate the MNM indicators

Objective of the study	Setting/ participants included	Deliveries	LB	No. MD	Total no. MNM	Indicators	Other major findings/ remarks
(70) Litorp et al., 2014 (Tanzania, 2012) Facility survey, QA score: Medium (14) Prospective CSS							
Examine the occurrence and explore their associations with CS compilations	Regional and university hospital Women admitted with complications during pregnancy, childbirth, or within 42 days after termination of pregnancy.	13,584	13,121	77	467	MNMR: 36 MI:14 87% of MNM were referred in critical situation which reflect a weak referral system	Major causes of MNM: hypertensive disorders and postpartum haemorrhage. Strong association between MNM and CS.
(71) Lotufo et al., 2012 (Brazil, 2010) Facility survey, QA score: Medium (11) Prospective CSS							
Assess severe maternal morbidity and MD admitted to ICU during and after pregnancy using WHO MNM criteria	1 teaching hospital Women admitted to ICU during pregnancy and postpartum period	NA	9,683	5	110	MNMR: 4.4 MI:10.4 Perinatal outcome: high prevalence of preterm deliveries among severe morbidity cases, a significantly high incidence of stillbirths among cases of MNM and maternal deaths	80% of the ICU admissions was due to obstetric cause Main causes of MNM: hTN and PPH
(72) Luexay et al., 2014 (Laos, 2010-2011) Survey in community and healthcare facility, QA score: Medium (12) Prospective cohort follow-up, Face to face interview from women							
Examine the burden of MNM and death at community and healthcare facility level	Communities in 4 districts in Sayaboury province 1215 pregnant women recruited and followed-up if developed SMO	1,215	1,125	2	11	SMOR: 11.6 MNMR: 9.8 MNM: 1MD 5.5: 1 MI:15.3	Majority of MNM detected during antenatal period Authors concluded that WHO criteria could not be used in the community and in the facilities, due to limited capacity of laboratory services in district hospital to confirm MNM, which led to underestimation of MNM Used modified WHO criteria

Objective of the study	Setting/ participants included	Deliveries	LB	No. MD	Total no. MNM	Indicators	Other major findings/ remarks
(73) Mbachu et al., (2017), Nigeria (2014-2015) Facility survey, QA score: High (18) Prospective CSS							
Examine causes of MNM, measure MNM indicators, and identify associated patient and healthcare factors	Private teaching hospital Women who died or had MNM from pregnancy, labour, and puerperal complications based on WHO definition	307	262	5	52	SMOR: 218, MNMR: 198, MNM: 1MD: 11.4: 1, MI: 8.8% Associated factors: administration 35.1%, medical team 47.4%, patient 77.2%	Used modified WHO criteria
(74) Madeiro et al., 2015 (Brazil, 6-months during 2012-2013) Facility survey, QA score: Medium (16) Prospective CSS							
Estimate the prevalence and explore the determinants of SMM and MNM	1 tertiary hospital Women admitted with severe complications during pregnancy, intrapartum, and up to 42 days postpartum period	-	5,841	10	353	SMOR: 11.3 MNMR: 9.6 MNM: 1MD: 5.6:1 MI: 15.2 Perinatal outcome: (Low Apgar score and LBW)	Main causes of MNM: hypertensive disorders and haemorrhage correlation between caesarean section, long hospitalisation and low Apgar score and MNM
(75) Mazhar et al., 2015 (Pakistan, 2011) Survey part of WHO multicounty survey, QA score: Medium (11) Prospective cross-sectional study							
Determine the incidence and demographic and obstetric factors associated with SMO	16 HCF across Pakistan as part of WHO multicounty survey, 13175 women attending for delivery at study site facilities	13,122	-	27	52	SMOR: 10 MNMR: 7 MNM: 1MD: 2.5:1 MI: 28.7 Use of prophylactic oxytocin for prevention of PPH	Intensive-care facilities were available for only 32.6% of women with SMOS 44.7% of maternal deaths occurred among women who had not received intensive care because resources were lacking Authors called for improving uniform implementation of obstetric care protocols

Objective of the study	Setting/ participants included	Deliveries	LB	No. MD	Total no. MNM	Indicators	Other major findings/ remarks
(76) Mohammadi et al., 2016 (Iran, 2012-2014) Facility survey, QA score: High (19) Case control							
Explore the frequency, causes, risk factors, and perinatal outcomes of MNM	2 secondary and 1 tertiary hospital Women experienced severe obstetric complications during pregnancy, delivery, or within 6 weeks postpartum,	13,169	12,965	12	82	SMOR: 7.2 MNMR: 6.3 MI: 13%	Main causes of MNM: PPH, severe preeclampsia (MNM, women with previous CS, co-morbidity had increased risk of MNM) Used modified WHO criteria
(77) Nadari et al., 2015 (Iran, 2013) Facility survey, QA score: Medium (12) Prospective CSS							
Determine the incidence and associate factors of severe maternal morbidity	8 hospitals (referral, public, private) in two cities Women admitted during pregnancy, childbirth or up to 42 days postpartum	-	19,908	2	501	MNMR: 29 MNM: 1 MD: 250:1 MI: 0.4%	Main causes of MNM: hypertension and haemorrhage
(78) Nielsen et al., 2013 (actually two studies in the same year; Tanzania, 2009-2011) Facility-based review, QA score: High (18) Prospective cross-sectional study							
Assess the occurrence of SAMM and MD to assess implementation levels of key interventions in SAMM and MD	1 rural hospital, Tanzania Women admitted during pregnancy, childbirth, and up to 42 days postpartum MNM or maternal death during the study period	9,471	9,136	32	216	SMOR: 27.1 MNMR: 23.6 MNM: 1MD: 6.8:1 MI: 12.9% Case fatality rate, hospital access indicators SMO at arrival 69.4% MI: 7.6% Intra hospital care: MI: 5.3% % of coverage of key based evidence interventions	Key evidence-based interventions were not implemented in MNM and maternal deaths cases Used modified WHO criteria - Haydom

Objective of the study	Setting/ participants included	Deliveries	LB	No. MD	Total no. MNM	Indicators	Other major findings/ remarks
(79) Norhyati et al., 2016 (Malaysia, 2014) Facility survey, QA score: Medium (13) Prospective CSS							
Examine severe maternal morbidity and MNM as proposed by WHO MNM approach	2 referral tertiary hospitals Postpartum women up to 42 days after termination of pregnancy	21,756	21,579	2	47	Severe maternal morbidity 18.1 per 1,000 LB MNMR: 2.2 MNM: 1MD: 23.5:1 MI:4.1% ICU admission: 72.3% 55% had MNM on arrival or within 12hrs of arrival % use key interventions	Main causes of MNM: obstetric haemorrhage and hypertensive disorders Main contributory condition to MNM: previous CS (36.3%) of MNM and anaemia (27.7%)
(80) Oladapo et al., 2016 (Nigeria, 2012-2013) National surveillance with criteria-based audit, QA score: High (18) Prospective CSS							
Examine the burden and causes of life-threatening maternal complications and the QoC	42 tertiary hospitals Women admitted for pregnancy, childbirth, and puerperal complications	97,634	91,724	998	1,451	SMOR: 26.7 MNMR: 15.8 MI: 40.8% Median time between diagnosis and initiation of definitive treatment: 60 minutes, and over 4 hrs in 1/5 of cases Median time interval between diagnosis and attendance of most senior doctor: 60 minutes and > 4 hrs in about 25% of cases Deficiency in care: 49.6% of SMO (42.6%) Factors associated with deficiency in care (administrative, patient-related, and medical team-related) Deficiency in the management of MNM: 42.4%	Most women admitted already in critical condition Factors associated with SMO: Late presentation of woman to the hospital (35.3%) Lack of health insurance/ inability to pay for required services (17.5%) Non-availability of required blood/blood products 12.7% Note: large network of tertiary hospitals Just using clinical criteria of the WHO criteria

Objective of the study	Setting/ participants included	Deliveries	LB	No. MD	Total no. MNM	Indicators	Other major findings/ remarks
(81) Oliveira, and da Costa, 2015 (Brazil, 2007-2010) Facility survey, QA score: Medium (14) Retrospective CSS							
Examine the epidemiological clinical profile of women with MNM	Single tertiary hospital Women with MNM and admitted to obstetric ICU Not specified GA	-	19,950	56	255	MNMR: 12.8 MNM: 1MD: 4.5:1 MI:18%	Main causes of MNM: hypertensive disorders and haemorrhage Only 4.9% of MNM did not attend ANC care Low QoC proposed as explanation for observation of high MNMR despite high % of women attending ANC
(82) Pacagenella et al., 2014 (Brazil, 2009-2010) National surveillance with criteria-based audit, QA score: High (19) Prospective CSS							
Examine delay in providing obstetric care and its association with severe maternal morbidity and death	27 obstetric referral hospitals in all regions of Brazil Women admitted with pregnancy related complications and found to have MNM/MD during pregnancy, childbirth, or 42 days postpartum	-	82,144	140	770	Positive association between the occurrence of any delay and severity of SMO Delay observed in 68% of MNM and 84% of MD cases Patient-related factors 10.2% Related to health service accessibility 34.6% Quality of provided medical care 25.7%	Part of Brazilian Network for Surveillance of Severe Maternal Morbidity Delays related to quality of provided care associated with "worse maternal outcome"
(83) Pacheco et al., 2014 (Brazil, 2012-2013) Criteria-based review, QA score: High (18) Retrospective cohort							
Determine the risk factors for severe maternal morbidity and MNM	One reference hospital for high obstetric care Pregnant or postpartum women admitted during the study period (2,291 pregnant or postpartum women) (unspecified GA)	2,291	-	-	400 (SMM) 24 NM		Delay in receiving care at the healthcare facility (OR: 13.3; 95% CI: 6.7 – 26.4) less than 6 ANC visits OR: 1.1; 95% CI: 1.01 – 1.69) Three delays model incorporated

Objective of the study	Setting/ participants included	Deliveries	LB	No. MD	Total no. MNM	Indicators	Other major findings/ remarks
(84) Panda et al., 2018 (India, 2017) Facility survey, QA score: Low (9) Retrospective CSS							
Examine the burden of MNM by measuring MNM indicators and explore the foetal outcome of women with MNM	Single hospital case fulfilling the WHO criteria, unspecified GA	1,406	1,349	8	89	SMOR: 71.9 MNMR: 65.9 MNM: 1MD: 11.1:1, MI:8.2%, Perinatal outcome: 7.9% of women with MNM had stillbirth, 49.4% of newborns had LBW	Main cause of MNM: severe pre-eclampsia
(85) Ps et al., 2013 (Brazil, 2012-2013) Facility survey, QA score: Low (9) Prospective CSS							
Measure the frequency of MNM, MNM indicators and compare MNM with maternal deaths	Tertiary hospital Admitted women with MNM or deaths during pregnancy, childbirth or 42 days postpartum	7,390	7,330	23	131	MNMR: 17.8 MNM: 1MD: 5.6:1 MI: 14.9%	Calculated MNM ratio and MI for each underlying cause Highest MI for haemorrhage and hypertensive disorders
(86) Rathod et al., 2016 (India, 2011-2013) Facility survey, QA score: Low (8) Retrospective cohort							
Analyse MNM and maternal deaths, explore the causes and measure indicators	Single referral tertiary hospital admitted obstetric patients fulfilling the WHO maternal deaths definition, unspecified GA	21,992	22,092	66	161	MNMR: 7.56, MNM: 1MD: 3.4:1 MI:29.1	Main cause of MNM: haemorrhage 18.6% of women with MNM were not registered for ANC
(87) Ray et al., 2016 (India, 2014-2015) Facility survey, QA score: Low (7) Prospective CSS							
Estimate the prevalence of MNM, and examine MNM and maternal deaths for auditing the QoC	Single referral hospital Participants not clearly specified	4,583	4,038	17	220	MNMR: 54.4 MNM: 1MD: 13:1 MI: 7.2% ICU admission rate: 62.6% of cases (MD and MNM)	Main causes of MNM: hypertensive disorders and haemorrhage (38.6%) were the leading causes

Objective of the study	Setting/ participants included	Deliveries	LB	No. MD	Total no. MNM	Indicators	Other major findings/ remarks
(88) Rulisa et al., 2015 (Rwanda, 2011-2012) Facility survey, QA score: Medium (14) Prospective CSS							
Measure the prevalence and explore factors associated with MNM and maternal deaths	Single teaching hospital Women admitted to hospital with severe maternal morbidity or mortality (GA unspecified)	-	1,739	50	142	SMOR: 11 MNMR: 8 MNM: 1MD 3.5: 1 MI: 0.26%	Main causes of MNM: peritonitis, hypertensive disorders, and obstetric haemorrhage Attributed to suboptimal management of high-risk patients at district hospitals Used modified WHO criteria
(89) Sangeeta et al., 2015 (Northern India, 2012-2013) Facility survey, QA score: Medium (11) Prospective CSS							
Measure the frequency and causes of MNM and MNM indicators	Single teaching hospital Women admitted with PTLC during antenatal, intrapartum, or 42 days' post termination of pregnancy	6,892	6,767	8	205	SMOR: 5.17 MNMR: 3.98 MNM: 1MD: 3.4:1 MI: 22.8% Intrahospital MNM: 1MD: 5.4: 1 intrahospital MI: 14.3%	Main cause of MNM: obstetric haemorrhage Main contributory condition: anaemia
(90) Sayinzoga et al., 2017 (Rwanda, 2015-2016) Facility survey, QA score: High (19) Prospective case control							
Analysis of severe maternal outcomes and measuring QoC indicators	Four district hospitals Admitted women with SMO during pregnancy, childbirth, and up to 42 days after termination of pregnancy Control selected from those who had given birth or were admitted with pregnancy complication but did not develop SMO within 48 hrs of occurrence of the case	-	5,577	13	201	SMOR: 38.4 MNMR: 36.0 MNM: 1MD: 15.5, MI: 6.1% SMO at arrival or within 12 h of hospital arrival MI: 4.8% Intra hospital MI: 15.4% % of coverage of key interventions	Main causes of MNM: PPH, uterine rupture, and abortion-related complications Main contributory conditions to MNM: previous caesarean section and anaemia Measuring coverage of essential interventions is insufficient to reduce SMO and to assess the QoC In-depth review of SMO is more useful to assess the implementations of these interventions Used modified WHO criteria

Objective of the study	Setting/ participants included	Deliveries	LB	No. MD	Total no. MNM	Indicators	Other major findings/ remarks
(91) Shahid, Rizwan and Khawaja, 2015 (Pakistan, 2014) Facility survey, QA score: Low (8) Retrospective CSS							
Assess the frequency of MNM events and their most common causes	Single tertiary hospital Obstetric patients fulfilling WHO near-miss criteria, unspecified GA	-	2,371	7	124	MNMR: 52 MNM: 1MD: 17:1 89% of cases had the severe complications on arrival	Main causes of MNM: obstetric haemorrhage and hypertensive disorders
(92) Soma-Pillay et al., 2015 (South Africa, 2013-2014) Population survey using hospital data, QA score: Medium (16) Prospective CSS							
Explore the spectrum of maternal morbidity and maternal mortality using WHO MNM criteria and indicators	9 hospitals from all levels in South Africa All women admitted to Pretoria Academic Complex facilities with severe complications/ during pregnancy, childbirth, or 42 days postpartum Excluded cases of abortion and ectopic pregnancy	26,614	-	19	136	SMOR: 5.1 MI: 14% Perinatal mortality: 198.0/1,000 for women with life-threatening conditions 22.2% of MNM were not registered for ANC or had infrequent ANC	4% of women developed a PTLC 0.5% developed a life-threatening condition, of whom 39.3% referred from PHC High % of women who developed severe maternal conditions were not identified during antenatal period Identified need to increase the number of routine ANC visits from 4 and to ensure that all levels of healthcare facilities can manage obstetric emergencies as well as strengthen emergency transport system
(93) Soma-Pillay and Pattinson, 2016 (South Africa, 2013-2015) Facility survey, QA score: with criteria-based audit, QA score: Medium (16) Prospective CSS							
Explore the delays/barriers in providing obstetric care to women with MNM	Single tertiary hospital Women fulfilling WHO MNM definition and criteria	-	-	-	100	Barriers in accessing care were identified in 83% of women with MNM Phase I and III had more frequent identified delays Lack of knowledge of the problem: 40%. Inadequate ANC: 37% Delay in referral, admission, or treatment: 37.0% Inappropriate diagnosis or treatment: 36.0%	Three-delay model used to evaluate reasons for delay

Objective of the study	Setting/ participants included	Deliveries	LB	No. MD	Total no. MNM	Indicators	Other major findings/ remarks
(94) Souza et al., 2012 (Brazil, 2009-2010) Facility survey, QA score: High (20) Prospective CSS							
Validate the WHO MNM criteria and develop tool for assessment of quality assessment tool using severe maternal morbidity	27 referral hospitals in Brazil All women admitted to the participating health facilities with PTLC, MNM, and MD based on WHO definition (during pregnancy, intrapartum or up to 42 days post termination of pregnancy)	82,388	82,144	140	910	Maternal severity index (MSI) used to describe the relationship between life-threatening conditions and mortality (Area under the ROC curve: 0.951 (95% CI 0.909–0.993))	MSI is a model developed to estimate the probability of maternal death using maternal severity score, predictors of maternal deaths (e.g. obstetric and demographic variables, causes of maternal deaths) and life-threatening conditions to assess the performance of health services and QoC assessment Universal coverage of life-saving interventions needs to be matched with emergency obstetric services and improvements in QoC
(95) Souza et al., 2013 (29 countries, 2010-2011) Global survey with criteria-based audit, QA score: High (20) Prospective CSS							
Determine the burden of complications related to pregnancy, the coverage of key maternal health interventions, and the use of the MSI	375 healthcare facilities 314,623 women screened to include women who had a maternal death or MNM up to 7 days after giving birth or an abortion, irrespective of gestational age or delivery status	314,623	310,435	486	2,538	SMOR: 9.9 MNMR: 8.3 Ratio of PTLC per 1,000 livebirths (7.5) Coverage of key interventions SMO: 78.5% for parental antibiotic for sepsis to 90.1% for prophylactic oxytocin Countries with MMR had high coverage of essential key interventions (e.g. 89.3% for parental antibiotic for sepsis to 90.7% for prophylactic oxytocin)	MSI was validated and found to be a good predictor for maternal death High coverage of essential interventions does not necessarily reduce severe maternal outcome It is necessary to evaluate delays in implementation of these key interventions

Objective of the study	Setting/ participants included	Deliveries	LB	No. MD	Total no. MNM	Indicators	Other major findings/ remarks
(96) Tuncalp et al., 2013 (Ghana, 2010-2011) Facility survey with criteria-based clinical audit, QA score: High (18) Prospective CSS							
Measure the incidence of MNM, indicators related to accessibility and QoC	1 tertiary hospital Women admitted with life-threatening conditions during antenatal, intrapartum, or 42 days' post termination of pregnancy, irrespective of GA	3,379	3,206	37	94	SMOR: 40.8 MNMR: 28.6 MNM: 1MD: 2.5:1 MI:28.2% >50% of MNM and MD occurred within 12 hrs of admission Hospital access indicators: 80% of the patients with SMO in first 12 hours were referred MI for cases with SMO within 12 hrs of admission: 16.4% Intra-hospital care MI 41.1% % of ICU admission among SMO: 19.1%	Only 62% of women who developed PPH received oxytocin Only 41% of women with sepsis received parenteral treatment Data were extracted from chart reviews, which were supplemented by information from healthcare providers when needed
(97) Woldeyes, Asefa and Muleta, 2018 (Ethiopia, 2015) Facility survey, QA score: High (18) Prospective CSS							
Estimate the incidence and determinants of SMO, assess the QoC	Single referral hospital Women with PLTC or SMO while pregnant, during childbirth, or within 42 days after termination of pregnancy, found to have SMO	-	2,737			SMOR: 59.2 MNMR: 50.4 MNM: 1MD: 5.8:1 MI:14.8% SMO identified on arrival or within 12 hrs of hospital admission: 71.6% Ratio of intrahospital SMO: 16.8 per 1000 LB	Main causes of MNM: uterine rupture, obstetric haemorrhage, hypertensive disorders SMO with delay in seeking care: 45.1% SMO with delay in reaching appropriate care: 57.1% SMO with delay in receiving appropriate care: 59.1%

Objective of the study	Setting/ participants included	Deliveries	LB	No. MD	Total no. MNM	Indicators	Other major findings/ remarks
(98) Yadav and Nada, 2016 (India, 2012-2014) Facility survey, QA score: Low (7) Prospective CSS							
Measure the incidence and causes of MNM and maternal deaths, and explore types of delays	Single tertiary hospital Women with MNM and MD fulfilling the WHO criteria without specifying the GA	-	15,170	60	184	SMOR: 17.6 MNMR: 13.2 MNM:1 MD:3.07:1 MI:25% First delay identified: MNM: 71.7%, MD: 90% Second delay identified: MNM: 37%, MD (25%), Associated factors related to infrastructure of healthcare facility: MNM: 44.6%, MD: 58.3% Non-availability of blood: MNM: 44%, MD: 55%	57.1% of MNM never received ANC Main causes of MNM: haemorrhage and hypertensive disorders MNM ICU admission rate: 32.1%

## Annex 2: Summary table for the reported WHO outcome indicators

Criteria	MNM ratio per 1000 LB	SMOR per 1000 LB	MNM: 1MD	MI (%)
<b>Disease-specific</b>	(n=6) - 10.5 (Naz et al., 2014) - 20.2 (David et al., 2008) - 22.1 (Ali et al., 2011) - 32.9 (Almerie et al., 2010) - 50 (Roost et al., 2009) - 76.96 (Siddiqui, Soomro and Shabih-UI-Hasani, 2012)	(n=1) - 22.7 (David et al., 2008)	(n=7) -3.5:1 (Naz et al., 2014) -5.8:1 (Siddiqui, Soomro and Shabih-UI-Hasani, 2012) - 7.4:1 (van den Akker et al., 2011) - 14:1 (Rabia et al., 2011) -35.6:1 (Ghazal-Aswad et al., 2013) -60.1:1 (Almerie et al., 2010) 100:1 (Tamura et al., 2012)	(n=5) -1.7 (Almerie et al., 2010) - 3.6 (Roost et al., 2009) - 11.2 (CFR (David et al., 2014) - 11.9 (CFR (van den Akker et al., 2011) -19.5 (Ali et al., 2011)
<b>Management-based criteria</b>	(n=1) -3.4 (Karolinski et al., 2005)	Not reported	(n=2) -8.5:1 (Donati, Senatore and Ronconi, 2012) -37.4:1 (Oliverira Neto et al., 2009)	Not reported
<b>Organ dysfunction</b>	(n=2) -6.1 per 1,000 births (Marr et al., 2014) - 43 (Chaudhuri and Nath, 2018)	(n=1) -49 (Chaudhuri and Nath, 2018)	(n=2) - 7.7: 1 (Chaudhuri and Nath, 2018) - 79:1 (Murphy et al., 2009)	Not reported
<b>Mixed</b>	(n=7) -2.9 (Gorbman et al., 2014) - 7.1 per, 1000 births (van Dillan et al., 2010) -12 (Assarag et al., 2015) -21.2 (Amaral et al., 2011) - 21.1 (Souza et al., 2010) -31.5 (Cecatti et al., 2015) - 43 (Chaudhuri and Nath, 2018)	Not reported	(n=2) -15:1 (Karolinski et al., 2013) -23.7:1 (Amaral et al., 2011)	(n=1) -6.2 (CFR) (Karolinski et al., 2013)
<b>WHO</b>	(n=18) - 2.2 (Norhyati et al., 2016)	(n=14) - 4.4 (Ashma, Gehanath and	(n=16) - 2.5:1 (Mazhar et al., 2015)	(n=14) - 0.2 (Ashma, Gehanath and Ganesh,

Criteria	MNM ratio per 1000 LB	SMOR per 1000 LB	MNM: 1MD	MI (%)
	<ul style="list-style-type: none"> <li>- 3.8 (Ashma, Gehanath and Ganesh, 2013)</li> <li>- 4.0 (Sangeeta et al., 2015)</li> <li>- 4.4 (Lotufo et al., 2012)</li> <li>- 4.8 (Jayaratnam et al., 2016)</li> <li>- 4.7 (Leme-Galvao et al., 2014)</li> <li>- 5.0 (Ghazivakili et al., 2016)</li> <li>- 5.1 (Jabir et al., 2010)</li> <li>- 5.8 (Iwuh, Fawcus and Schoeman, 2018)</li> <li>- 5.9 (El Ghardallou et al. (2016))</li> <li>- 6 (Jayaratnam et al., 2011)</li> <li>- 7 (Mazhar et al., 2015)</li> <li>- 7 (Jayaratnam et al., 2018)</li> <li>- 7.5 (Rathod et al., 2016)</li> <li>- 7.8 (Bashour et al., 2015)</li> <li>- 8 (Rulisa et al., 2015)</li> <li>- 8.0 (Ewnetu Firdawek et al., 2017)</li> <li>- 8.3 (Souza et al., 2013)</li> <li>- 9.3 (Cecatti et al., 2016)</li> <li>- 9.6 (Madeiro et al., 2015)</li> <li>- 10.2 (Dias et al., 2014)</li> <li>- 13.2 (Shaveta, and Nanda 2016))</li> <li>- 12.3 (De Mucio et al., 2016)</li> <li>- 15.2 (Abha, Chandrashekhar and Sonal, 2016)</li> <li>- 17.8 (Ps et al., 2013)</li> <li>- 25.4 (Bolnga et al., 2017)</li> <li>- 28 (Tuncalp et al., 2013)</li> <li>- 29 (Nadari et al., 2015)</li> </ul>	<ul style="list-style-type: none"> <li>Ganesh, 2013).</li> <li>- 5.1 (Soma-Pillay et al., 2015)</li> <li>- 5.2 (Ghazivakili et al., 2016)</li> <li>- 5.2 (Sangeeta et al., 2015)</li> <li>- 5.7 (Jabir et al., 2010)</li> <li>- 5.8 (Jayaratnam et al., 2016)</li> <li>- 5.8 (Leme-Galvao et al., 2014)</li> <li>- 5.9 El Ghardallou, M. Et al. (2016)</li> <li>- 6.5 (Iwuh, I. A. Et al., 2018)</li> <li>- 7 (Jayaratnam et al., 2011)</li> <li>- 8.6 (Bashour et al., 2015)</li> <li>- 9.9 (Souza et al., 2013)</li> <li>- 10 (Mazhar et al., 2015)</li> <li>- 10.6-11.4 (Haddad et al., 2014).</li> <li>- 11.0 (Cecatti et al., 2016)</li> <li>- 11 (Rulisa et al., 2015)</li> <li>- 11.3 (Madeiro et al., 2015)</li> <li>- 12.9 (De Mucio et al., 2016)</li> <li>- 17.6 (Shaveta, and Nanda 2016)</li> <li>- 27.1 (Bolnga et al., 2017)</li> <li>- 40.8 (Tuncalp et al., 2013)</li> <li>- 59.2 (Woldeyes, Asefa and Muleta, 2018)</li> <li>- 71.9 (Panda et al., 2018)</li> <li>- 88.66 (Bakshi et al., 2015)</li> </ul>	<ul style="list-style-type: none"> <li>- 2.5:1 (Tuncalp et al., 2013)</li> <li>- 3.1: 1 (Shaveta, and Nanda 2016)</li> <li>- 3.4:1 (Sangeeta et al., 2015)</li> <li>- 3.4: 1 (Rathod et al., 2016)</li> <li>- 3.5:1 (Rulisa et al., 2015)</li> <li>- 4.1:1 (Leme-Galvao et al., 2014)</li> <li>- 5.1: 1 (Bakshi et al., 2015)</li> <li>- 5.5: 1 (Cecatti et al., 2016)</li> <li>- 5.6:1 (Madeiro et al., 2015)</li> <li>- 5.6:1 (Ps et al., 2013)</li> <li>- 5.8:1 (Woldeyes, Asefa and Muleta, 2018)</li> <li>- 6:1 (Ashma, Gehanath and Ganesh, 2013)</li> <li>- 6.7 (Kiruja et al., 2017)</li> <li>- 8.6:1 (Iwuh, Fawcus and Schoeman, 2018)</li> <li>- 9:1 (Jabir et al., 2010)</li> <li>- 8.4: 1- 10:1 (Haddad et al., 2014)</li> <li>- 10:1 (Jayaratnam et al., 2016)</li> <li>- 11.1: 1 (Panda et al., 2018))</li> <li>- 11.8:1 (Bashour et al., 2015)</li> <li>- 13:1 (Ray et al., 2016)</li> <li>- 15.3:1 (Bolnga et al., 2017)</li> <li>- 17:1 (Shahid, Rizwan and Khawaja, 2015)</li> <li>- 19.1 (De Mucio et al., 2016)</li> <li>- 23.5: 1 (Norhyati et al., 2016)</li> <li>- 27.4: 1 (Ghazivakili et al., 2016)</li> <li>- 30.8:1 (Dias et al., 2014)</li> <li>- 58:1 (El Ghardallou et al., 2016)</li> <li>- 250:1 (Nadari et al., 2015)</li> </ul>	<ul style="list-style-type: none"> <li>2013)</li> <li>- 1, 7 (El Ghardallou et al., 2016)</li> <li>- 3.5 (Ghazivakili et al., 2016)</li> <li>- 4.1 (Norhyati et al., 2016)</li> <li>- 5.1 (De Mucio et al., 2016)</li> <li>- 6.8 (Bolnga et al., 2017)</li> <li>- 7.2 (Ray et al., 2016)</li> <li>- 7.8 (Bashour et al., 2015)</li> <li>- 8.2 (Panda et al., 2018)</li> <li>- 10.4 (Lotufo et al., 2012)</li> <li>- 10.4 (Iwuh, Fawcus and Schoeman, 2018)</li> <li>- 14 (Litorp et al., 2014)</li> <li>- 14 (Soma-Pillay et al., 2015)</li> <li>- 14.8 (Woldeyes, Asefa and Muleta, 2018)</li> <li>- 14.9 (Ps et al., 2013)</li> <li>- 15.4 (Cecatti et al., 2016)</li> <li>- 15.8 (Madeiro et al., 2015)</li> <li>- 16.4 (Bakshi et al., 2015)</li> <li>- 18 (Leme-Galvao et al., 2014)</li> <li>- 22.8 (Sangeeta et al., 2015)</li> <li>- 25 (Shaveta, and Nanda 2016)</li> <li>- 28.2 (Tuncalp et al., 2013)</li> <li>- 28.7 (Mazhar et al., 2015)</li> <li>- 29.1 (Rathod et al., 2016)</li> </ul>

Criteria	MNM ratio per 1000 LB	SMOR per 1000 LB	MNM: 1MD	MI (%)
	<ul style="list-style-type: none"> <li>- 36 (Litorp et al., 2014)</li> <li>- 50.4 (Woldeyes, Asefa and Muleta, 2018)</li> <li>- 52 (Shahid, Rizwan and Khawaja, 2015)</li> <li>- 54.4 (Ray et al., 2016)</li> <li>- 65.9 (Panda et al., 2018)</li> <li>- 88.6 (Kiruja et al., 2017)</li> </ul>			
<b>Modified WHO</b>	(n=9) <ul style="list-style-type: none"> <li>-6.3 (Mohammadi et al., 2016)</li> <li>- 8 (Rulisa et al., 2015)</li> <li>- 9 (Herklots et al., 2017)</li> <li>- 9.8 (Luexay et al., 2014).</li> <li>- 15.8 (Oladapo et al., 2015)</li> <li>- 21.5 (Kalisa et al., 2016)</li> <li>-23.6 (Nelissen et al., 2013)</li> <li>- 36.0 (Sayinzoga et al., 2017)</li> <li>- 198 (Mbachu et al., 2017)</li> </ul>	(n=9) <ul style="list-style-type: none"> <li>- 7.2 (Mohammadi et al. (2016)</li> <li>-11 (Rulisa et al., 2015)</li> <li>- 11.6 (Luexay et al., 2014)</li> <li>- 16 (Herklots et al., 2017)</li> <li>- 24.8 (Kalisa et al., 2016)</li> <li>- 26.7 (Oladapo et al., 2015)</li> <li>- 27.1 (Nelissen et al., 2013)</li> <li>- 38.4 (Sayinzoga et al., 2017)</li> <li>- 218 (Mbachu et al., 2017)</li> </ul>	(n=7) <ul style="list-style-type: none"> <li>- 1.3: 1 (Herklots et al., 2017)</li> <li>- 3.5: 1 (Rulisa et al., 2015)</li> <li>- 5.5:1 (Luexay et al., 2014)</li> <li>- 6.8:1 (Nelissen et al., 2013)</li> <li>- 7: 1 (Kalisa et al., 2016)</li> <li>- 11.4:1 (Mbachu et al., 2017)</li> <li>- 15.5: 1 (Sayinzoga et al., 2017)</li> </ul>	(n=7) <ul style="list-style-type: none"> <li>- 0.3 (Rulisa et al., 2015)</li> <li>- 8.8 (Mbachu et al., 2017)</li> <li>- 12.9 (Nielsen et al., 2013)</li> <li>- 13 (Mohammadi et al. (2016)</li> <li>- 13.1 (Kalisa et al., 2016)</li> <li>- 15.3 (Luexay et al., 2014)</li> <li>- 22.8 (Sayinzoga et al., 2017)</li> <li>- 43 (Herklots, et al., 2017)</li> <li>-40.8 (Oladapo et al., 2015)</li> </ul>

### Annex 3: Potentially Life-Threatening Condition Form

Name of Hospital: \_\_\_\_\_

Completed by Member of Staff						Completed by Focal Person		
S/N	Patient name/ hospital number	Date of admission	Place of admission	Type of complication	Date of developing the complication	Was the complication detected first in this facility? Yes/No, referred from other facility (Please state the name of health facility)	Fulfil maternal near-miss (Yes/No)	Outcome on discharge Dead Discharged Referred

## Annex 4: Maternal Near-Miss Identification Form

<b>Form 2: Maternal "Near-Miss" Identification Form</b>	
<b><u>Purpose of form:</u></b>	
This maternal near-miss identification form is designed to be used by focal person in the health facility to report the identified maternal near-miss cases up to 42 days post delivery who are admitted to the health facility.	
The form is divided into two parts:	
<b>Part A:</b> This part includes general information about the mother, list of Potentially life Threatening Conditions and Maternal near-miss criteria.	
<b>Part B:</b> This part is meant to capture additional information about maternal near-miss cases and it should be completed only if woman fulfills the criteria of maternal near-miss.	
<b><u>Who should use the form:</u></b>	
The focal person should fill the form within 7 days of the woman discharge from hospital using the information available in the hospital file and antenatal record (ANC record).	
<b><u>How to complete the form:</u></b>	
Put a cross (X) in the box as appropriate or answer the question in the space provided as explained in the study manual using only <b>BLACK</b> pen.	
To fill section 7 (Identification criteria for maternal near-miss), please select the broader group to which the woman's severe complication belongs, e.g. if she had severe infection which is related to pregnancy, select the pregnancy related infection option.	
If you do not know the answers to some questions, this should be indicated in the respective section (e.g. Unknown)	
If you encounter any problems while completing the form, please contact the central focal person in the Department of Women and Child Health-Ministry of Health-HQ (Phone No. 24946361, Email: <a href="mailto:dfchmail@gmail.com">dfchmail@gmail.com</a> < <a href="mailto:dfchmail@gmail.com">mailto:dfchmail@gmail.com</a> >) or the principle investigator ( <a href="mailto:Jamila.AI-Abri@lstmed.ac.uk">Jamila.AI-Abri@lstmed.ac.uk</a> ).	
Once the form is completed, it should be forwarded to the Head of Woman and Child Health in the respective governorate. For health facilities located in Muscat Governorate, the form should be sent directly to the central focal person in the Department of Women and Child Health-Ministry of Health-HQ.	

<b>Section 1: General Information</b>							
1.1 Name of Reporting Facility:	<input style="width: 100%;" type="text"/>						
1.2 Facility Code:	<input style="width: 40px;" type="text"/> (Please refer to the end of the form for correct facility spelling and I.D)						
1.3 Individual Identification No:	<input style="width: 60px;" type="text"/>						
1.4 ANC Number (If booked):	<input style="width: 40px;" type="text"/> <input style="width: 40px;" type="text"/> <input style="width: 40px;" type="text"/>						
1.5 Name of focal Person:	<input style="width: 100%;" type="text"/>						
1.6 Signature of Focal Person:	<input style="width: 100%; height: 20px;" type="text"/>						
1.7 Date of completion of form:	<table style="width: 100%; border: none;"> <tr> <td style="text-align: center; font-size: small;">Day</td> <td style="text-align: center; font-size: small;">Month</td> <td style="text-align: center; font-size: small;">Year</td> </tr> <tr> <td style="border: 1px solid black; width: 30px; height: 20px;"></td> <td style="border: 1px solid black; width: 30px; height: 20px;"></td> <td style="border: 1px solid black; width: 40px; height: 20px;"></td> </tr> </table>	Day	Month	Year			
Day	Month	Year					





**4.5** Is this pregnancy a result of assisted reproduction?  Yes  No  Unknown

**4.6** Type of pregnancy:  Single  Multiple Pregnancy  Unknown

Please specify details (twin, multiple, etc)

**4.7** During this current pregnancy where there any other complication (s):  No  Yes

If yes specify type of complication:

1)

2)

3)

4)

5)

**4.8** Was the woman admitted before during the current pregnancy?  Yes  No  Unknown

If yes please specify the number of admissions:

*If yes please specify details of admissions:*

Date of admission:	Place of admission:	Reason for admission:
<input style="width: 10px;" type="text"/> / <input style="width: 10px;" type="text"/> / <input style="width: 10px;" type="text"/> <input style="width: 10px;" type="text"/> <input style="width: 10px;" type="text"/> <input style="width: 10px;" type="text"/>	<input style="width: 100%;" type="text"/>	<input style="width: 100%;" type="text"/>
<input style="width: 10px;" type="text"/> / <input style="width: 10px;" type="text"/> / <input style="width: 10px;" type="text"/> <input style="width: 10px;" type="text"/> <input style="width: 10px;" type="text"/> <input style="width: 10px;" type="text"/>	<input style="width: 100%;" type="text"/>	<input style="width: 100%;" type="text"/>
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<input style="width: 10px;" type="text"/> / <input style="width: 10px;" type="text"/> / <input style="width: 10px;" type="text"/> <input style="width: 10px;" type="text"/> <input style="width: 10px;" type="text"/> <input style="width: 10px;" type="text"/>	<input style="width: 100%;" type="text"/>	<input style="width: 100%;" type="text"/>
<input style="width: 10px;" type="text"/> / <input style="width: 10px;" type="text"/> / <input style="width: 10px;" type="text"/> <input style="width: 10px;" type="text"/> <input style="width: 10px;" type="text"/> <input style="width: 10px;" type="text"/>	<input style="width: 100%;" type="text"/>	<input style="width: 100%;" type="text"/>



## Part A

### Section 5: Medical History

5.1 Did the woman have any pre-existing medical problems?  Yes  No

If yes please specify:

1. \_\_\_\_\_
2. \_\_\_\_\_
3. \_\_\_\_\_
4. \_\_\_\_\_
5. \_\_\_\_\_

### Section 6: Current Admission

6.1 What was the date of hospital admission?  /  /

6.2 What was the date of hospital discharge?  /  /

6.3 Timing of admission:

Antenatal: Specify gestational age -

Intrapartum

Postpartum: Specify how many days postpartum -

6.4 Type of admission:

Planned admission

Self-Referral

Referred from another facility:   
(Please specify referred facility name)

### Section 7: Identification of Maternal Near-Miss

What was the severe complication during this admission?	Please specify the conditions	Did she have any of the following potentially life threatening conditions?	Did she have any of the following markers?
<input type="checkbox"/> Pregnancy with abortive outcome	<input type="checkbox"/> Ruptured ectopic pregnancy	<input type="checkbox"/> Severe Haemorrhage (Bleeding of 1000 ml or more or any bleeding with hypotension or blood transfusion)	Please select one or more as applicable
			<input type="checkbox"/> Shock (Persistent severe hypotension (a persistent BP < 80 mmHg or persistent systolic BP < 90 mmHg for 60 minutes with a pulse rate at least 120 despite fluid replacement (> 2L)). <input type="checkbox"/> Blood Transfusion (five or more units of blood transfusion within 24 hours) <input type="checkbox"/> Hysterectomy for Haemorrhage <input type="checkbox"/> Coagulopathy (acute thrombocytopenia (< 500,000 platelets), (low fibrinogen (<100 mg/dl), (Prolonged prothrombin time (.6s, INR >5), or elevated D-dimer (>100 mg/dl)



■ Part A

Section 7: Identification of Maternal Near-Miss (Continued)			
What was the severe complication during this admission?	Please specify the conditions	Did she have any of the following potentially life threatening conditions?	Did she have any of the following markers?
<b>Please select one or more as applicable</b>			
	<input type="checkbox"/> Misscarriage with excessive bleeding	<input type="checkbox"/> Massive Pulmonary Embolism	<input type="checkbox"/> Severe Hypotension <input type="checkbox"/> Shock (A persistent systolic blood pressure <80 mmHg or a persistent systolic blood pressure <90 mmHg with a pulse rate at least 120 beats per minute) <input type="checkbox"/> Cardiac Arrest <input type="checkbox"/> Collapse <input type="checkbox"/> Severe Hypoxaemia (Oxygen saturation < 90% for 60 min /PO2/FiO2<200) <input type="checkbox"/> ECHO (Finding of RV Dysfunction) <input type="checkbox"/> Myocardial Injury (R. Ventricular dysfunction)(elevated cardiac troponin I or -T concentrations in plasma), or heart failure as a result of (right) ventricular dysfunction) <input type="checkbox"/> Computed Tomographic Pulmonary Angiography Finding of Massive Pulmonary Embolism
	<input type="checkbox"/> Abortion with excessive bleeding	<input type="checkbox"/> Sepsis	<input type="checkbox"/> Severe Sepsis (sepsis associated with organ dysfunction, hypo-perfusion, or hypotension which may include but not limited to lactic acidosis, oliguria, or an acute alteration in mental status) <input type="checkbox"/> Admission to high dependency unit or ICU <input type="checkbox"/> Septic Shock (persistence of hypo-perfusion despite adequate fluid replacement therapy)
	<input type="checkbox"/> Molar pregnancy	<input type="checkbox"/> Thyroid Crisis	<input type="checkbox"/> Central nervous symptoms (Delirium, psychosis, seizure, coma) <input type="checkbox"/> Congestive heart failure <input type="checkbox"/> Atrial fibrillation <input type="checkbox"/> Tachycardia (Pulse rate > 140/min) <input type="checkbox"/> Severe gastrointestinal / hepatic dysfunction (unexplained jaundice) <input type="checkbox"/> Hyperthermia (Temperature >40C)
<input type="checkbox"/> Hypertensive Conditions	<input type="checkbox"/> Pre-existing hypertension with superimposed proteinuria <input type="checkbox"/> Pregnancy induced hypertension with or without proteinuria	<input type="checkbox"/> Severe Pre-Eclampsia <input type="checkbox"/> Eclampsia	<input type="checkbox"/> Pulmonary Oedema (breathlessness, orthopnoea, agitation, cough, tachycardia, tachypnoea, crackles and wheeze on chest auscultation, cardiac S3 gallop rhythm and murmurs, decreased oxygen saturation) <input type="checkbox"/> Jaundice <input type="checkbox"/> Eclampsia <input type="checkbox"/> Thrombocytopenia (platelets count <100,000/uL) <input type="checkbox"/> Impaired Renal Function (Serum creatinine mg/L or a doubling of the serum creatinine concentration in the absence of other renal disease) <input type="checkbox"/> Impaired Liver Function (Serum aspartate aminotransferase 70 IU/L or greater OR Gamma-glutamyltransferase 70 IU/L or greater Alanine aminotransferase 70 IU/L or greater)



## Part A

Section 7: Identification of Maternal Near-Miss (Continued)			
What was the severe complication during this admission?	Please specify the conditions	Did she have any of the following potentially life threatening conditions?	Did she have any of the following markers?
		<input type="checkbox"/> HELLP Syndrome	Please select one or more as applicable <input type="checkbox"/> Haemolysis (abnormal (fragmented or contracted red cells) peripheral blood smear or serum lactate dehydrogenase levels 600 IU/L or greater or total bilirubin 20.5 micromole/L or greater) <input type="checkbox"/> Elevated Liver Enzymes (Serum aspartate aminotransferase 70 IU/L or greater OR Gamma-glutamyltransferase 70 IU/L or greater Alanine aminotransferase 70 IU/L or greater) <input type="checkbox"/> Low Platelet (Less than 100,00 x109/L)
<input type="checkbox"/> Obstetric Haemorrhage	<input type="checkbox"/> Antepartum <input type="checkbox"/> Intrapartum <input type="checkbox"/> Postpartum	<input type="checkbox"/> Severe Haemorrhage (Bleeding of 1000 ml or more or any bleeding with hypotension or blood transfusion)	<input type="checkbox"/> Shock (Persistent severe hypo-tension (a persistent BP < 80 mmHg or persistent systolic BP < 90 mmHg for 60 minutes with a pulse rate at least 120 despite fluid replacement (> 2L)). <input type="checkbox"/> Coagulopathy (acute thrombocytopenia (<50 000 platelets), low fibrinogen (<100 mg/dl), prolonged prothrombin time (>6s, INR>5), or elevated D-dimer (>1000 ng/dl)) <input type="checkbox"/> Blood Transfusion (five or more units of blood transfusion within 24 hours) <input type="checkbox"/> Hysterectomy for Haemorrhage
<input type="checkbox"/> Pregnancy Related Infection	<input type="checkbox"/> Infection of Genitourinary Tract <input type="checkbox"/> Chorioamnionitis <input type="checkbox"/> Puerperal Sepsis	<input type="checkbox"/> Sepsis	<input type="checkbox"/> Severe Sepsis (sepsis associated with organ dysfunction, hypo-perfusion, or hypotension which may include but not limited to lactic acidosis, oliguria, or an acute alteration in mental status) <input type="checkbox"/> Admission to high dependency unit or ICU <input type="checkbox"/> Septic Shock (persistence of hypo-perfusion despite adequate fluid replacement therapy)
<input type="checkbox"/> Other Obstetric Complications	<input type="checkbox"/> Obstetric Embolism	<input type="checkbox"/> Amniotic Fluid Embolism  <input type="checkbox"/> Massive Pulmonary Embolism	<input type="checkbox"/> Acute Hypotension (systolic BP < 90 mmHg) <input type="checkbox"/> Coagulopathy (acute thrombocytopenia (<50 000 platelets), low fibrinogen (<100 mg/dl), prolonged prothrombin time (>6s, INR>5), or elevated D-dimer (>1000 ng/dl)) <input type="checkbox"/> Cardiac Arrest (sudden absence of pulse and loss of consciousness) <input type="checkbox"/> Seizure  <input type="checkbox"/> Severe Hypotension <input type="checkbox"/> Shock (A persistent systolic blood pressure < 80 mmHg or a persistent systolic blood pressure < 90 mmHg with a pulse rate at least 120 beats per minute) <input type="checkbox"/> Cardiac Arrest <input type="checkbox"/> Collapse <input type="checkbox"/> Severe Hypoxaemia (Oxygen saturation < 90% for 60 min /PO2/FIO2<200) <input type="checkbox"/> ECHO finding of RV dysfunction <input type="checkbox"/> Myocardial Injury (R. Ventricular dysfunction (elevated cardiac troponin I or -T concentrations in plasma), or heart failure as a result of (right) ventricular dysfunction) <input type="checkbox"/> Computed Tomographic Pulmonary Angiography Finding of Massive Pulmonary Embolism



■ **Part A** ■

<b>Section 7: Identification of Maternal Near-Miss (Continued)</b>			
What was the severe complication during this admission?	Please specify the conditions	Did she have any of the following potentially life threatening conditions?	Did she have any of the following markers?
<b>Please select one or more as applicable</b>			
	<input type="checkbox"/> Liver Disease in Pregnancy	<input type="checkbox"/> Acute Fatty Liver	<input type="checkbox"/> Hepatic Encephalopathy (presence of neuropsychiatric symptoms and signs such as abnormal movements like shaking hands, agitation, disorientation, drowsiness or confusion, etc). <input type="checkbox"/> Convulsion <input type="checkbox"/> Renal Impairment (increase in Creatinine and urea) <input type="checkbox"/> Coagulopathy (acute thrombocytopenia (<50 000 platelets), low fibrinogen (<100 mg/dl), prolonged prothrombin time (>6s, INR>5), or elevated D-dimer (>1000 ng/dl)) <input type="checkbox"/> Admission to High Dependency Area or ICU <input type="checkbox"/> Intubation or Ventilation not related to anaesthesia <input type="checkbox"/> Renal Dialysis
	<input type="checkbox"/> Obstetric Trauma	<input type="checkbox"/> Postpartum Inversion to Uterus <input type="checkbox"/> Obstetric Trauma/Injury to Bladder & other abdominal or pelvic organs	<input type="checkbox"/> Acute Hypotension (systolic BP <90 mmHg) <input type="checkbox"/> Neurogenic Shock (pale, and sweating, with profound hypotension with bradycardia) <input type="checkbox"/> Hypovolemic Shock (A persistent systolic blood pressure <80 mmHg or a persistent systolic blood pressure <90 mmHg with a pulse rate at least 120 beats per minute) <input type="checkbox"/> Blood Transfusion (Transfusion of 5 or more unit of blood)
	<input type="checkbox"/> Intentional Self-Harm	<input type="checkbox"/> Suicidal Attempts	<input type="checkbox"/> Total Paralysis <input type="checkbox"/> Coma <input type="checkbox"/> Cardiac Arrest (absence of pulse/heart beat and loss of consciousness) <input type="checkbox"/> Coagulopathy (acute thrombocytopenia (<50 000 platelets), low fibrinogen (<100 mg/dl), prolonged prothrombin time (>6s, INR>5), or elevated D-dimer (>1000 ng/dl)). <input type="checkbox"/> Azotaemia (Creatinine $\mu$ mol/l or 3.5 mg/dl) <input type="checkbox"/> Hepatic Dysfunction <input type="checkbox"/> Dialysis for Acute Renal Failure <input type="checkbox"/> Intubation and Ventilation <input type="checkbox"/> Cardiorespiratory Resuscitation
	<input type="checkbox"/> Venous Complications	<input type="checkbox"/> Cerebral venous thrombosis	<input type="checkbox"/> Seizure <input type="checkbox"/> Neurological deficit (paresis, dysphasia) <input type="checkbox"/> Impaired consciousness (GCS <14) <input type="checkbox"/> Coma (GCS <4) <input type="checkbox"/> Papilledema



**Section 7: Identification of Maternal Near-Miss (Continued)**

What was the severe complication during this admission?	Please specify the conditions	Did she have any of the following potentially life threatening conditions?	Did she have any of the following markers?
<b>Please select one or more as applicable</b>			
	<input type="checkbox"/> Cardiac Complication	<input type="checkbox"/> Peripartum cardiomyopathy	<input type="checkbox"/> Pulmonary oedema <input type="checkbox"/> Shock (Persistent severe hypo-tension (a persistent BP < 80mmHg or persistent systolic BP <90 mmHg for 60 minutes with a pulse rate at least 120 despite fluid replacement (>2L)) <input type="checkbox"/> Cardiac arrest (sudden absence of pulse and loss of consciousness) <input type="checkbox"/> Severe hypo-perfusion <input type="checkbox"/> Cardiopulmonary resuscitation <input type="checkbox"/> Use of continuous vasoactive drug <input type="checkbox"/> Intubation and ventilation
<input type="checkbox"/> Un-anticipated complications of management	<input type="checkbox"/> Complication of Anaesthesia	<input type="checkbox"/> Cerebral Anoxia <input type="checkbox"/> Aspiration Pneumonitis <input type="checkbox"/> Cardiac Failure <input type="checkbox"/> Subdural Haematoma <input type="checkbox"/> Cerebral Venous Sinus Thrombosis <input type="checkbox"/> Post-dural Anaesthesia <input type="checkbox"/> Other - <i>Specify</i>	<input type="checkbox"/> Collapse after Anaesthesia <input type="checkbox"/> Persistent Severe Headache <input type="checkbox"/> Cardiac Arrest (sudden absence of pulse and loss of consciousness) <input type="checkbox"/> Admission to ICU due to Anaesthetic Complications <div style="border: 1px solid black; height: 30px; width: 100%; margin-top: 10px;"></div>
	<input type="checkbox"/> Infection	<input type="checkbox"/> Severe Pneumonia  <input type="checkbox"/> Sepsis	<input type="checkbox"/> Severe Sepsis (sepsis associated with organ dysfunction, hypo-perfusion, or hypotension which may include but not limited to lactic acidosis, oliguria, or an acute alteration in mental status. <input type="checkbox"/> Admission to high dependency area or ICU  <input type="checkbox"/> Septic Shock (persistence of hypoperfusion despite adequate fluid replacement therapy)



■ Part A

Section 7: Identification of Maternal Near-Miss (Continued)			
What was the severe complication during this admission?	Please specify the conditions	Did she have any of the following potentially life threatening conditions?	Did she have any of the following markers?
<b>Please select one or more as applicable</b>			
	<input type="checkbox"/> Cardiac (including pre-existing hypertension) conditions	<input type="checkbox"/> Acute Myocardial Infarction <input type="checkbox"/> Infective Endocarditis <input type="checkbox"/> Pulmonary Hypertension <input type="checkbox"/> Dissection of Aortic Aneurysm <input type="checkbox"/> Acute Heart Failure <input type="checkbox"/> Acute Atrial Fibrillation <input type="checkbox"/> Acute severe hypertension (systolic BP >160 mmHG, diastolic BP >100mmHG) <input type="checkbox"/> Severe valvular heart disease <input type="checkbox"/> Cardiomyopathy	<input type="checkbox"/> Pulmonary Oedema (breathlessness, orthopnoea, agitation, cough, tachycardia, tachypnoea, crackles and wheeze on chest auscultation, cardiac S3 gallop rhythm and murmurs, decreased oxygen saturation) <input type="checkbox"/> Shock (Persistent severe hypo-tension (systolic BP <90 mmHg for 60) minutes with a pulse rate at least 120 despite fluid replacement (> 2L)) <input type="checkbox"/> Cardiac Arrest (absence of pulse/heart beat and loss of consciousness) <input type="checkbox"/> Severe Hypoperfusion (Lactates >5 mmol/L or >45 mg/dl, severe acidosis) <input type="checkbox"/> Cardiopulmonary Resuscitation <input type="checkbox"/> Use of contineous vasoactive drug <input type="checkbox"/> Intubation and Ventilation <input type="checkbox"/> Stroke
	<input type="checkbox"/> Respiratory Condition	<input type="checkbox"/> Severe Asthma <input type="checkbox"/> Severe Chronic Bronchitis <input type="checkbox"/> Pulmonary Oedema <input type="checkbox"/> Pneumothorax <input type="checkbox"/> Acute Respiratory Distress Syndrome	<input type="checkbox"/> Acute Cyanosis <input type="checkbox"/> Gasping <input type="checkbox"/> Respiratory Rate (>40 or <6 bpm) <input type="checkbox"/> Oxygen Saturation (<90% for >60 min PaO2<200mmHg) <input type="checkbox"/> Intubation and Ventilation
	<input type="checkbox"/> Genitourinary Conditions	<input type="checkbox"/> Acute Renal Failure	<input type="checkbox"/> Oliguria non-resonsive to Fluids or Diuretics <input type="checkbox"/> Creatinine (>300 µmol/l or 3.5 mg/dl) <input type="checkbox"/> Renal Dialysis
	<input type="checkbox"/> Haematological Conditions	<input type="checkbox"/> Sickle cell disease with crisis  <input type="checkbox"/> Thrombotic Thrombocytopenic Purpura	<input type="checkbox"/> Acute chest syndrome <input type="checkbox"/> Admission to High Dependency Area or ICU <input type="checkbox"/> Hyper haemolysis and severe anaemia <input type="checkbox"/> Evidence of multi-organ failure <input type="checkbox"/> Severe infection or evidence of sepsis <input type="checkbox"/> Pulmonary embolism  <input type="checkbox"/> Severe renal impairment <input type="checkbox"/> Neurological involvement <input type="checkbox"/> Cardiac involvement <input type="checkbox"/> Admission to High Dependency Area / ICU



■ Part A

Section 7: Identification of Maternal Near-Miss (Continued)			
What was the severe complication during this admission?	Please specify the conditions	Did she have any of the following potentially life threatening conditions?	Did she have any of the following markers? Please select one or more as applicable
<b>Please select one or more as applicable</b>			
	<input type="checkbox"/> Endocrine Conditions	<input type="checkbox"/> Thyroid Crisis  <input type="checkbox"/> Diabetes Ketoacidosis	<input type="checkbox"/> Central nervous symptoms (Delirium, psychosis, seizure, coma) <input type="checkbox"/> Congestive heart failure <input type="checkbox"/> Atrial fibrillation <input type="checkbox"/> Tachycardia (Pulse rate > 140/min) <input type="checkbox"/> Severe gastrointestinal / hepatic dysfunction (unexplained jaundice) <input type="checkbox"/> Hyperthermia (Temperature >40C)
	<input type="checkbox"/> Central Nervous Conditions	<input type="checkbox"/> Epilepsy <input type="checkbox"/> Intracerebral and Subarachnoid Haemorrhage <input type="checkbox"/> Convulsion of unknown origin	<input type="checkbox"/> Acute Respiratory Distress Syndrome (respiratory failure with bilateral infiltration) <input type="checkbox"/> Disorientation/Coma <input type="checkbox"/> Severe Acidaemia [(PH< 7.1) bicarbonate< 10 mEq/L (10 mmol/L)] <input type="checkbox"/> Severe Hypokalemia  <input type="checkbox"/> Uncontrollable fit/status epilepticus <input type="checkbox"/> Total Paralysis <input type="checkbox"/> Stroke <input type="checkbox"/> Prolonged Unconsciousness/Coma (lasting >12 hours)
	<input type="checkbox"/> Connective Tissue Conditions	<input type="checkbox"/> Flare of Systematic Lupus Erythematosus <input type="checkbox"/> Anti-phospholipid Syndrome with Complications	<input type="checkbox"/> Presence of Organ Failure
<input type="checkbox"/> Non-obstetric Complications	<input type="checkbox"/> Gastrointestinal tract conditions	<input type="checkbox"/> Severe non-pregnancy related liver diseases	<input type="checkbox"/> Severe ascites <input type="checkbox"/> Oesophageal variceal bleeding <input type="checkbox"/> Hepatic encephalopathy <input type="checkbox"/> Coagulopathy (Acute thrombocytopenia (<50 000 platelets), low fibrinogen (<100 mg/dl), prolonged prothrombin time (>6s, INR>5), or elevated D-dimer (>1000 mg/dl))
		<input type="checkbox"/> Ruptured appendix <input type="checkbox"/> Acute pancreatitis <input type="checkbox"/> Acute cholecystitis <input type="checkbox"/> Perforated gastro-duodenal ulcer <input type="checkbox"/> Intestinal obstruction/perforation	<input type="checkbox"/> Severe sepsis (sepsis associated with organ dysfunction, hypo-perfusion, or hypotension which may include but not limited to lactic acidosis, oliguria, or an acute alteration in mental status.) <input type="checkbox"/> Shock (Persistent severe hypo-tension (systolic BP <90 mmHg for 60) minutes with a pulse rate at least 120 despite fluid replacement (> 2L))  <input type="checkbox"/> Intubation and ventilation not related to anaesthesia  <input type="checkbox"/> Cardiopulmonary resuscitation



Section 7: Identification of Maternal Near-Miss (Continued)			
What was the severe complication during this admission?	Please specify the conditions	Did she have any of the following potentially life threatening conditions?	Did she have any of the following markers? Please select one or more as applicable
		Please select one or more as applicable	
<input type="checkbox"/> Other severe conditions	<input type="checkbox"/> Specify the condition: <div style="border: 1px solid black; height: 150px; width: 100%;"></div>	<input type="checkbox"/> Permanent Neurological Injury  <input type="checkbox"/> Prolonged unconsciousness / coma (lasting more than 12 hours) <small>(Persistent severe hypo-tension (a persistent BP &lt; 80mmHg or persistent systolic BP &lt;90 mmHg for 60 minutes with a pulse rate at least 120 despite fluid replacement (&gt;2L))</small> <input type="checkbox"/> Shock <input type="checkbox"/> Coagulopathy <small>(Acute thrombocytopenia (&lt;50 000 platelets), low fibrinogen (&lt;100 mg/dl), prolonged prothrombin time (&gt;6s, INR&gt;5), or elevated D-dimer (&gt;1000 mg/dl))</small> <input type="checkbox"/> Organ Failure - Specify <input style="width: 100px; height: 15px;" type="text"/>  <input type="checkbox"/> Intubation & ventilation not related to anaesthesia  <input type="checkbox"/> Cardiopulmonary resuscitation  <input type="checkbox"/> Emergency obstetric hysterectomy	
	<b>Does the woman have any of the above maternal near-miss markers?</b>		
<input type="checkbox"/> Potentially Life Threatening Condition  <input type="checkbox"/> Maternal Near-Miss  <input type="checkbox"/> Maternal Death			



## Part B

### Section 8: Additional Information for Identified Cases Of Maternal Near-Miss

**8.1** When did the complications occur?  Antenatal, specify gestational age:    
 Intrapartum  
 Postpartum: specify how many days after delivery

**8.2** For cases of haemorrhage what was the cause of haemorrhage?  
 Placental abruption  Rupture of uterus  Pelvic haematoma  Vaginal laceration  
 Placenta previa/accrete/increta/percreta  Uterine atony  Laceration of cervix  Other

**8.3** Was the woman admitted to ICU/CCU?  No  
 Yes: Date of admission  /  /

If yes, please specify the total number of days she stayed in ICU/CCU

**8.4** Was the woman admitted to HDU?  No  
 Yes: Date of admission  /  /

If yes, please specify the total number of days she stayed in HDU:

**8.5** Did she have interventional radiology during this admission?  No  
 Yes: Date of procedure  /  /

If yes specify type:

**8.6** Did she have surgery during this admission?  No  Yes  
 If Yes, please specify (select one or more as applicable):  Dilation & Curettage  Hysterectomy  Caesarean Section  Re-laparotomy  
 Other

**8.7** Did she receive any blood or blood products?  No  Yes: Specify Product & Units

	Product	Unit		Product	Unit
A)	<input type="text"/>	<input type="text"/> <input type="text"/>	C)	<input type="text"/>	<input type="text"/> <input type="text"/>
B)	<input type="text"/>	<input type="text"/> <input type="text"/>	D)	<input type="text"/>	<input type="text"/> <input type="text"/>
E)	<input type="text"/>	<input type="text"/> <input type="text"/>			

**8.8** Were any of the following conditions present?  
 Grand-multiparty (delivered >5)  Previous caesarean section  Maternal pelvic abnormality  
 Prolonged obstructed labour  Premature rupture of membrane  Failed trial of labour  
 Failed induction of labour  Failed vacuum extraction or forceps  Multiple gestation  
 Preterm labour  Prolonged pregnancy  Oligohydramnios  
 Polyhydramnios  Foetal abnormality  Abnormal presentation of fetus  
 Anaemia  Diabetes  HIV + Status  
 Complication of anaesthesia  Others (please specify)  None identified  
 Medical disorder (below)



## ■ Part B ■

Section 9: Miscarriage	
9.1 Did the woman have an abortion/ miscarriage during the current pregnancy?	<input type="checkbox"/> No <input type="checkbox"/> Yes
9.2 If yes, please state:	<input type="checkbox"/> Miscarriage <input type="checkbox"/> Hydatidiform Mole <input type="checkbox"/> Ectopic <input type="checkbox"/> Termination of Pregnancy
Section 10: Delivery	
10.1 Did the woman deliver?	<input type="checkbox"/> Yes, Date: <input type="text"/> / <input type="text"/> / <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="checkbox"/> No
10.2 Where did delivery occur at:	<input type="checkbox"/> Home <input type="checkbox"/> Health facility <input type="checkbox"/> Other (Please specify) <input type="text"/>
10.3 What was the mode of delivery?	<input type="checkbox"/> Spontaneous Vaginal Delivery <input type="checkbox"/> Caesarean Section Hysterectomy <input type="checkbox"/> Induced Vaginal Delivery <input type="checkbox"/> Caesarean Section Elective <input type="checkbox"/> Caesarean Section Emergency <input type="checkbox"/> Assisted Delivery (ventouse, forceps)
10.4 What was the condition of baby at birth?	<input type="checkbox"/> Stillbirth <input type="checkbox"/> Macerated stillbirth <input type="checkbox"/> Fresh stillbirth <input type="checkbox"/> Alive
10.5 In case of multiple deliveries, please comment on the mode of delivery and condition of the new-borns if they were different from each other:	<input type="text"/>
Section 11: Neonatal Outcome	
11.1 Was the baby admitted to the Special Care baby Unit?	<input type="checkbox"/> Yes <input type="checkbox"/> No
If yes to question 11.1, please give the reason:	<input type="text"/>
11.2 What was the condition of baby at day 7 of life:	<input type="checkbox"/> Dead <input type="checkbox"/> Alive and well <input type="checkbox"/> Alive and still on treatment
11.3 In the case of multiple deliveries, please comment on the admission of new-borns to SCBU or their conditions at 7 days if they were different from each other:	<input type="text"/>



■ **Part B** ■

**Section 12: Additional Information**

Please use this space to enter any other information/comments you feel might be important.



## Annex 5: Assessors Form

Form 3: Assessors Form for Maternal Near-Miss	
<b><u>Purpose of this form</u></b>	This Assessor's form for maternal near-miss is designed as a template tool to facilitate a systematic and comprehensive analysis of a maternal near-miss case and to record the findings of the Assessor.
<b><u>Who should use the form</u></b>	This form should be used by local Assessors as well as the Assessors in the National Maternal Mortality Committee.
<b><u>How to complete the form</u></b>	Please complete this form using <b>BLACK</b> pen only and putting a cross (X) in the box where needed.
	The form should be completed for each maternal near-miss after a woman is discharged from the health facility. To conduct in-depth review of the case, the Assessor needs to collect woman's medical records including her ANC card, her medical record at primary health care level and copy of Form (2) the maternal near-miss identification form.
	The Assessors should fully understand the chain of events related to the maternal near-miss case, identify the main problems in the management of the case from the time before admission to discharge. This will assist in identifying the underlying cause of maternal near-miss and factors that might have adversely affected care. Positive aspects (strengths) identified in the care provided to woman should be acknowledged.
	During the review process, it is necessary to examine: <ol style="list-style-type: none"> <li>a. The adequacy of the available information</li> <li>b. The appropriateness of diagnostic and treatment provided according to national and known international standards for the management of such case.</li> </ol> For any queries, please contact the central focal point in the Department of Woman and Child Health-Ministry of Health-HQ (Telephone No.24946361, Email <a href="mailto:dfchmail@gmail.com">dfchmail@gmail.com</a> < <a href="mailto:dfchmail@gmail.com">mailto:dfchmail@gmail.com</a> >) or the principle investigator ( <a href="mailto:Jamila.Al-Abri@lsmmed.ac.uk">Jamila.Al-Abri@lsmmed.ac.uk</a> < <a href="mailto:Jamila.Al-Abri@lsmmed.ac.uk">mailto:Jamila.Al-Abri@lsmmed.ac.uk</a> >)

Section 1: General Information							
1.1 Facility Name:	<input style="width: 100%;" type="text"/>						
1.2 Facility Code:	<input style="width: 50%;" type="text"/>						
1.3 Individual Identification Number:	<input style="width: 50%;" type="text"/>						
1.4 ANC Number (if booked):	<input style="width: 20%;" type="text"/> . <input style="width: 20%;" type="text"/> . <input style="width: 20%;" type="text"/>						
1.5 Assessors name:	<input style="width: 100%;" type="text"/>						
1.6 Assessors contact number:	<input style="width: 100%;" type="text"/>						
1.7 Date of completion of the form:	<table style="width: 100%; border: none;"> <tr> <td style="text-align: center; font-size: small;">Day</td> <td style="text-align: center; font-size: small;">Month</td> <td style="text-align: center; font-size: small;">Year</td> </tr> <tr> <td style="border: 1px solid black; width: 20px; height: 20px;"></td> <td style="border: 1px solid black; width: 20px; height: 20px;"></td> <td style="border: 1px solid black; width: 20px; height: 20px;"></td> </tr> </table>	Day	Month	Year			
Day	Month	Year					
1.8 Assessors signature:	<div style="border: 1px solid black; height: 30px; width: 100%;"></div>						



**Section 2: Obstetric History**

2.1 Total number of previous pregnancies:	<input type="text"/>	<input type="text"/>
2.2 Total number of previous deliveries	<input type="text"/>	<input type="text"/>
2.3 Total number of previous abortions:	<input type="text"/>	<input type="text"/>
2.4 Total number of previous stillbirths:	<input type="text"/>	<input type="text"/>
2.5 Total number of previous caesarean sections:	<input type="text"/>	<input type="text"/>

**Section 3: Current Pregnancy**

3.1 ANC booking status:	<input type="checkbox"/> Booked	<input type="checkbox"/> Unbooked	<input type="checkbox"/> Unknown
3.2 Gestational age at booking:	<input type="text"/>	<input type="text"/>	
3.3 Total number of ANC visits during current pregnancy:	<input type="text"/>	<input type="text"/>	
3.4 During this pregnancy where there any other complications: (if yes, please specify):	<input type="checkbox"/> Yes	<input type="checkbox"/> No	
<input type="text"/>			
<input type="text"/>			
<input type="text"/>			

**Section 4: Underlying cause of maternal near-miss**

4.1 What was the reported cause of maternal near-miss in the Maternal near-miss identification form (Form 2)?	<input type="text"/>
4.2 What in your opinion was the underlying cause of maternal near-miss after your in-depth review of the case?	
i) Disease or condition leading directly to a near-miss event	<input type="text"/>
ii) Due to or consequences of	<input type="text"/>
iii) Which is due to or consequences of	<input type="text"/>



**Section 5: Timing and place of occurrence of maternal near-miss**

5.1 Did the woman have the near-miss event:

Before admission

Within 12 hours of admission to the first hospital?

Within 24 hours of admission to the first hospital?

5.2 Please specify the place where the maternal near-miss event occurred:

At Home

Primary Health Centre

Local Hospital

Willayte (District) Hospital

Regional (Secondary Care) Hospital

Tertiary Care Hospital

5.3 In relation to pregnancy when did the maternal near-miss occur?

Antenatal, specify gestational age    Unknown

Intrapartum

Postpartum, specify how many days after delivery    Unknown

**Section 6: Contributory conditions to maternal near-miss (Please select the contributory conditions)**

Maternal	Foetus	Interventions
<input type="checkbox"/> Multiparty <input type="checkbox"/> Previous caesarean section <input type="checkbox"/> Maternal pelvic abnormality <input type="checkbox"/> Prolonged obstructed labour <input type="checkbox"/> Premature rupture of membranes <input type="checkbox"/> Preterm labour/birth <input type="checkbox"/> Prolonged pregnancy (>42 weeks of gestation) <input type="checkbox"/> Anaemia (Hb <11.0g/dl) <input type="checkbox"/> Diabeties <input type="checkbox"/> Other medical disorder (specify) <input type="text"/>	<input type="checkbox"/> Multiple gestation <input type="checkbox"/> Foetal abnormality <input type="checkbox"/> Abnormal presentation of foetus <input type="checkbox"/> Polyhydramnios <input type="checkbox"/> Oligohydramnios <input type="checkbox"/> Others (specify below) <input type="text"/>	<input type="checkbox"/> Failed induction of labour <input type="checkbox"/> Failed trial of labour <input type="checkbox"/> Failed vacuum extraction or forceps <input type="checkbox"/> Complication of anaesthesia <input type="checkbox"/> Others (specify below) <input type="text"/>
	<input type="checkbox"/> None identified	



**Section 7: Quality of care**

7.1 Are there any identified concerns regarding the quality of care the woman received before development of the severe complications?

- Yes       No       Inadequate information to comment

If yes, please specify:

**7.2 Referral:**

**If referred patient: (from lower level facility)**

7.2.1 Was the timing of referral appropriate?

- Yes       No       Inadequate information to comment

If no, please specify:

7.2.2 Were conditions of transfer appropriate (i.e. mode of transport, escorted by qualified escort team, first treatment was given)?

- Yes       No       Inadequate information to comment

If no, please specify:

**If self-referral and a complication arose before admission:**

7.2.3 Was the decision to seek care at a health facility taken in time?

- Yes       No       Inadequate information to comment

If no, please specify:

7.2.4 Was it possible for the woman to have reached the health facility in time?

- Yes       No       Inadequate information to comment

If no, please specify:



**7.3 Admission:**

7.3.1 If the woman experienced the severe complication before admission

Time woman arrived at the facility:   :

Time of first assessment:   :

7.3.2 Was there any delay in the first assessment of the woman in relation to her condition?

Yes       No       Inadequate information to comment

If no, please specify:

7.3.3 Was staff response in the admission room (emergency department) acceptable in relation to the woman's condition and standard of care (e.g. rapid call for senior staff, supportive first care)?

Yes       No       Inadequate information to comment

If no, please specify:

**7.4 Diagnosis**

7.4.1 How appropriate was the diagnosis at admission on the basis of available information at that time?

Appropriate       Inappropriate       Inadequate information to comment

Please explain why

**If woman already experienced the severe complication at the time of admission**

7.4.2 Time between admission and diagnosis:   :

7.4.3 Is the time between admission and diagnosis acceptable?

Yes       No       Inadequate information to comment

**If woman already experienced the severe complication during her stay in hospital**

7.4.4 Time between developing the complication and diagnosis:   :

7.4.3 Is the time taken to diagnosis acceptable in relation to standards of care?

Yes       No       Inadequate information to comment

If no, please specify



**7.5 Management**

7.5.1. Were investigations necessary for diagnosis requested and carried out in relation to womans condition and standard of care?

Yes     Some     No     Inadequate information to comment     Not applicable

If some or no, please specify

7.5.2 Were actions taken based on the results from the requested investigations?

Yes     No     Inadequate information to comment

If no, please specify

7.5.3 Were appropriate interventions (e.g. prescription of life saving medication, surgery, delivery of the foetus) for the severe complication done based on diagnosis and in relation to standards of care?

Yes     No     Inadequate information to comment

If no, please specify

7.5.4 Time interval between diagnosis and surgery in hours:

 : 

7.5.5 Is the time between diagnosis and surgery was acceptable in relation to the womans condition and standards of care?

Yes     No     Inadequate information to comment

If no, please specify

7.5.6 Were the appropriate medications given without delay based on the diagnosis and standard of care?

Yes     No     Inadequate information to comment     Not applicable

If no, please specify





**Section 8: Root cause analysis for the reason/s behind the identified dysfunction (delay /or inadequate) in management of the maternal near-miss case**

List the identified delay or in-adequate management in section (6) and reasons behind it/ them by asking the questions why until you identify the root cause of the problem e.g. if the woman had postpartum haemorrhage and there was failure to control the haemorrhage, you ask why there was a failure to control the haemorrhage? There was no oxytocin - Why there was no oxytocin? Oxytocin was out of stock? - Why was the oxytocin out of stock?

Identified delay or inadequate management	Reason/s why it occurred
	1 2 3 4 5



**Section 9: Summary of identified factors contributing to the maternal near-miss**

<input type="checkbox"/> Staffing (inadequate number of staff, non-availability of senior staff, etc)	
<input type="checkbox"/> Guidelines/Policies (Non-availability or un-updated guidelines)	
<input type="checkbox"/> Equipment (Non-availability, non-functioning, etc)	
<input type="checkbox"/> Medication/Blood Product	
<input type="checkbox"/> Referral Problem (Transportation, non-availability of bed in higher facility, non-availability of ICU bed)	
<input type="checkbox"/> Woman/Family (refusal of treatment, non-compliance)	
<input type="checkbox"/> Other Factors	

**Section 10: Assessment of care:**

<input type="checkbox"/> Overall there was good care
<input type="checkbox"/> Improvements in quality of care were identified, if these had been in place would still have made no difference to the outcome
<input type="checkbox"/> Improvements in quality of care identified, if these had been in place they may have made a difference to the outcome



**Section 11: Lessons Learned**

As a result of this review, what recommendations would you make to improve quality of care:

- 1) \_\_\_\_\_  
\_\_\_\_\_
- 2) \_\_\_\_\_  
\_\_\_\_\_
- 3) \_\_\_\_\_  
\_\_\_\_\_
- 4) \_\_\_\_\_  
\_\_\_\_\_
- 5) \_\_\_\_\_  
\_\_\_\_\_

**Section 12: Documents used in the review**

12.1 Please identify which documents you used for this review:

- ANC Card
- Primary Health Care notes
- Transfer (Referral) notes
- Patient's Hospital life
- Partogram
- Theatre notes (Operation notes)

12.2 Was all the required information available in the documents you reviewed?

- Yes
- No

If no, please specify:



**Section 13: Summary of the case**

Please write a narrative summary of the case which should be comprehensive, precise, and provide facts about the relevant events that occurred before the woman experienced the complication(s) until she was discharged

Present symptoms:

Key findings on admission:

Key findings on hospital stay:



Key findings on progress of labour (if applicable):
Key findings on intra-operation (if applicable):
Key findings on post-operation period (if applicable):
Key findings on postnatal period (if applicable):



## Annex 6: Committee Form

Form 4: Committee Form for Review of Maternal Near-Miss							
<p><b>Purpose of the form:</b> This committee form for review of maternal near-miss is designed as a template tool to facilitate a systematic and comprehensive analysis of the case by the Regional Maternal Mortality Committee and the National Maternal Mortality Committee. It should be used to record the committee consciences on underlying cause of, contributory conditions and factors contributing to maternal near-miss.</p> <p><b>Who should complete the form:</b> The rapporteur of the committee should complete the form for each maternal near-miss case during the committee meeting.</p> <p><b>How to complete the form:</b> The committee should discuss the case systematically to fully understand the chain of events related to the case, identify the main problems in the management of the case from the time before admission to the discharge of woman from the hospital. Positive aspects (strengths) observed in the care provided should also be identified and acknowledged.</p> <p>Based on the discussion the chairman of the committee should summarize the main points and consensus of the members. The rapporteur should record these points in the form.</p> <p>For any quires, please contact the central focal point in the Department of Woman and Child Health-Ministry of Health-HQ (Telephone No.24946361, Email <a href="mailto:dfchmail@gmail.com">dfchmail@gmail.com</a> &lt;<a href="mailto:dfchmail@gmail.com">mailto:dfchmail@gmail.com</a>&gt;) or the principle investigator (<a href="mailto:Jamila.Al-Abri@Ismed.ac.uk">Jamila.Al-Abri@Ismed.ac.uk</a>)</p>							
<b>Section 1: General Information</b>							
1.1 Meeting of:	<input type="checkbox"/> National Committee <input type="checkbox"/> Regional Committee, specify the governorate <input style="width: 150px; height: 20px;" type="text"/>						
1.2 Date of meeting:	<table style="width: 100%; border-collapse: collapse;"> <tr> <td style="text-align: center; font-size: small;">Day</td> <td style="text-align: center; font-size: small;">Month</td> <td style="text-align: center; font-size: small;">Year</td> </tr> <tr> <td style="text-align: center;"><input style="width: 20px; height: 20px;" type="text"/></td> <td style="text-align: center;"><input style="width: 20px; height: 20px;" type="text"/></td> <td style="text-align: center;"><input style="width: 20px; height: 20px;" type="text"/></td> </tr> </table>	Day	Month	Year	<input style="width: 20px; height: 20px;" type="text"/>	<input style="width: 20px; height: 20px;" type="text"/>	<input style="width: 20px; height: 20px;" type="text"/>
Day	Month	Year					
<input style="width: 20px; height: 20px;" type="text"/>	<input style="width: 20px; height: 20px;" type="text"/>	<input style="width: 20px; height: 20px;" type="text"/>					
1.3 Facility name:	<input style="width: 100%; height: 20px;" type="text"/>						
1.4 Facility Code:	<input style="width: 30px; height: 20px;" type="text"/>						
1.5 Individual identification number:	<input style="width: 40px; height: 20px;" type="text"/>						
1.6 ANC Number:	<input style="width: 30px; height: 20px;" type="text"/> <input style="width: 30px; height: 20px;" type="text"/> <input style="width: 30px; height: 20px;" type="text"/>						
1.7 Name of person completing the form:	<input style="width: 100%; height: 20px;" type="text"/>						
1.8 Contact Number:	<input style="width: 100%; height: 20px;" type="text"/>						
1.9 Date of completion of the form:	<table style="width: 100%; border-collapse: collapse;"> <tr> <td style="text-align: center; font-size: small;">Day</td> <td style="text-align: center; font-size: small;">Month</td> <td style="text-align: center; font-size: small;">Year</td> </tr> <tr> <td style="text-align: center;"><input style="width: 20px; height: 20px;" type="text"/></td> <td style="text-align: center;"><input style="width: 20px; height: 20px;" type="text"/></td> <td style="text-align: center;"><input style="width: 20px; height: 20px;" type="text"/></td> </tr> </table>	Day	Month	Year	<input style="width: 20px; height: 20px;" type="text"/>	<input style="width: 20px; height: 20px;" type="text"/>	<input style="width: 20px; height: 20px;" type="text"/>
Day	Month	Year					
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1.10 Signature of person completing the form:	<input style="width: 100%; height: 30px;" type="text"/>						



**Section 2: Demographic Characteristics**

2.1 Age:

2.2 Nationality:  Omani  Non-Omani

2.3 Marital Status:  Married  Divorced  Widow  Single  Unknown

2.4 The highest completed education level:  No Schooling  College  
 Primary  Postgraduate  
 Middle School  Unknown  
 Secondary School

2.5 Address:

City:

Village:

**Section 3: Obstetric History**

3.1 Total number of previous pregnancies:

3.2 Total number of previous deliveries:

3.3 Total number of previous abortions:

3.4 Total number of previous stillbirths:

3.5 Total number of living children:

3.6 Total number of previous caesarean sections:

**Section 4: Current Pregnancy**

4.1 ANC booking status:  Booked  Un-booked

4.2: Gestational age at booking:   weeks

4.3 Name of parent institution:

4.4 Total number of antenatal visits during this current pregnancy:

4.5 During this current pregnancy where there other complications:  Yes  No

If yes, please specify:



**Section 5: Underline cause of severe maternal complication**

*The disease or condition that initiated the morbid chain of events leading to maternal near-miss.  
Please select from the following group and then write the specific underlying from the ICD list (select only one).*

The Group	The Specific Cause	ICD Code
<input type="checkbox"/> Pregnancy with abortive outcome		□ □ □ □ . □
<input type="checkbox"/> Hypertensive disorder		□ □ □ □ . □
<input type="checkbox"/> Obstetric Haemorrhage		□ □ □ □ . □
<input type="checkbox"/> Pregnancy related infection		□ □ □ □ . □
<input type="checkbox"/> Other obstetric complications		□ □ □ □ . □
<input type="checkbox"/> Un-anticipated complications of management		□ □ □ □ . □
<input type="checkbox"/> Non-obstetric complications		□ □ □ □ . □

**Section 6: Contributory conditions to maternal near-miss (Please select the contributory conditions)**

Maternal	Foetus	Interventions
<input type="checkbox"/> Multiparty <input type="checkbox"/> Previous caesarean section <input type="checkbox"/> Maternal pelvic abnormality <input type="checkbox"/> Prolonged obstructed labour <input type="checkbox"/> Premature rupture of membranes <input type="checkbox"/> Preterm labour/birth <input type="checkbox"/> Prolonged pregnancy (>42 weeks of gestation) <input type="checkbox"/> Anaemia (Hb <11.0g/dl) <input type="checkbox"/> Diabetes <input type="checkbox"/> Other medical disorder (specify) <div style="border: 1px solid black; height: 20px; width: 100%;"></div>	<input type="checkbox"/> Multiple gestation <input type="checkbox"/> Foetal abnormality <input type="checkbox"/> Abnormal presentation of foetus <input type="checkbox"/> Polyhydramnios <input type="checkbox"/> Oligohydramnios <input type="checkbox"/> Others (specify below) <div style="border: 1px solid black; height: 40px; width: 100%;"></div>	<input type="checkbox"/> Failed induction of labour <input type="checkbox"/> Failed trial of labour <input type="checkbox"/> Failed vacuum extraction or forceps <input type="checkbox"/> Complication of anaesthesia <input type="checkbox"/> Others (specify below) <div style="border: 1px solid black; height: 40px; width: 100%;"></div>
	<input type="checkbox"/> None identified	



**Section 7: Management of Maternal Near-Miss**

7.1 Positive aspects identified in the case management:

- 1) \_\_\_\_\_  
\_\_\_\_\_
- 2) \_\_\_\_\_  
\_\_\_\_\_
- 3) \_\_\_\_\_  
\_\_\_\_\_
- 4) \_\_\_\_\_  
\_\_\_\_\_
- 5) \_\_\_\_\_  
\_\_\_\_\_

7.2 Problems/dysfunctions identified in the case management:

- 1) \_\_\_\_\_  
\_\_\_\_\_
- 2) \_\_\_\_\_  
\_\_\_\_\_
- 3) \_\_\_\_\_  
\_\_\_\_\_
- 4) \_\_\_\_\_  
\_\_\_\_\_
- 5) \_\_\_\_\_  
\_\_\_\_\_



7.3 Please specify the location of the problems/dysfunctions in the case management (please tick all applicable)						
Problem/Dysfunction	Primary Health Care Centre	Local Hospital	Wilayte (District Hospital)	Regional (Secondary Care) Hospital	Tertiary Care Hospital	Private Clinic /Hospital
Initial assessment	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Recognition/diagnosis	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Referral	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Managed at inappropriate level	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inappropriate management	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Involvement of senior health provider	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Monitoring of the patient	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Not managed at this level	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
No identified problem	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Lack of information	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

### Section 8: Factors contributing to Maternal Near-Miss

8.1 Please select all applicable factors that contributed to the maternal near-miss

a) Organizational Factors

<input type="checkbox"/> Staffing	<input type="checkbox"/> Inadequate number of staff	<input type="checkbox"/> Poor access to senior staff
<input type="checkbox"/> Policies and Guidelines	<input type="checkbox"/> Non-availability of policies <input type="checkbox"/> Non-availability of guidelines	<input type="checkbox"/> Un-updated guidelines
<input type="checkbox"/> Equipment	<input type="checkbox"/> Non-availability of equipment	<input type="checkbox"/> Non-functioning or old equipment
<input type="checkbox"/> Medication	<input type="checkbox"/> Non-availability of medication	
<input type="checkbox"/> Blood	<input type="checkbox"/> Non-availability of blood	
<input type="checkbox"/> Referral	<input type="checkbox"/> Transportation issue	<input type="checkbox"/> Non-availability of bed in higher facility
<input type="checkbox"/> Laboratory	<input type="checkbox"/> Non-availability of test <input type="checkbox"/> Delay access to test results	<input type="checkbox"/> Inaccurate results
<input type="checkbox"/> Other		



b) Health care team factors	
	Identified reason/s from root cause analysis
<input type="checkbox"/> Incomplete or delay in first assessment	
<input type="checkbox"/> Failure of recognition or seriousness of condition	
<input type="checkbox"/> Failure to assess severity and detect deterioration (poor monitoring)	
<input type="checkbox"/> Delay of diagnosis	
<input type="checkbox"/> Inappropriate management	
<input type="checkbox"/> Failure or delay in emergency response	
<input type="checkbox"/> Communication failure between professional	
<input type="checkbox"/> Delay in referral to higher care facility	
<input type="checkbox"/> Failure/late involvement of other specialities	
<input type="checkbox"/> Other, please specify	
c) Factors related to woman or her family	
	Identified reason/s from root cause analysis
<input type="checkbox"/> No ANC care	
<input type="checkbox"/> Late booking for ANC (>14 weeks of gestation)	
<input type="checkbox"/> Delay in seeking health care	
<input type="checkbox"/> Not adherent to the treatment of advice	
<input type="checkbox"/> Declining medication/procedure	
<input type="checkbox"/> Long distance from health facility	
<input type="checkbox"/> Others, please specify	



**Section 9: Overall assessment of care**

Please comment on the overall assessment of care

Overall there was good care

Improvement in quality of care were identified, if these had been in place it would still have made no difference to the outcome

Improvement in quality of care identified, if these had been in place it may have made a difference to the outcome

**Section 10: Lesson/s learned (Recommendations)**

As a result of this review what recommendations would you make to improve quality of care?

1) \_\_\_\_\_

2) \_\_\_\_\_

3) \_\_\_\_\_

4) \_\_\_\_\_

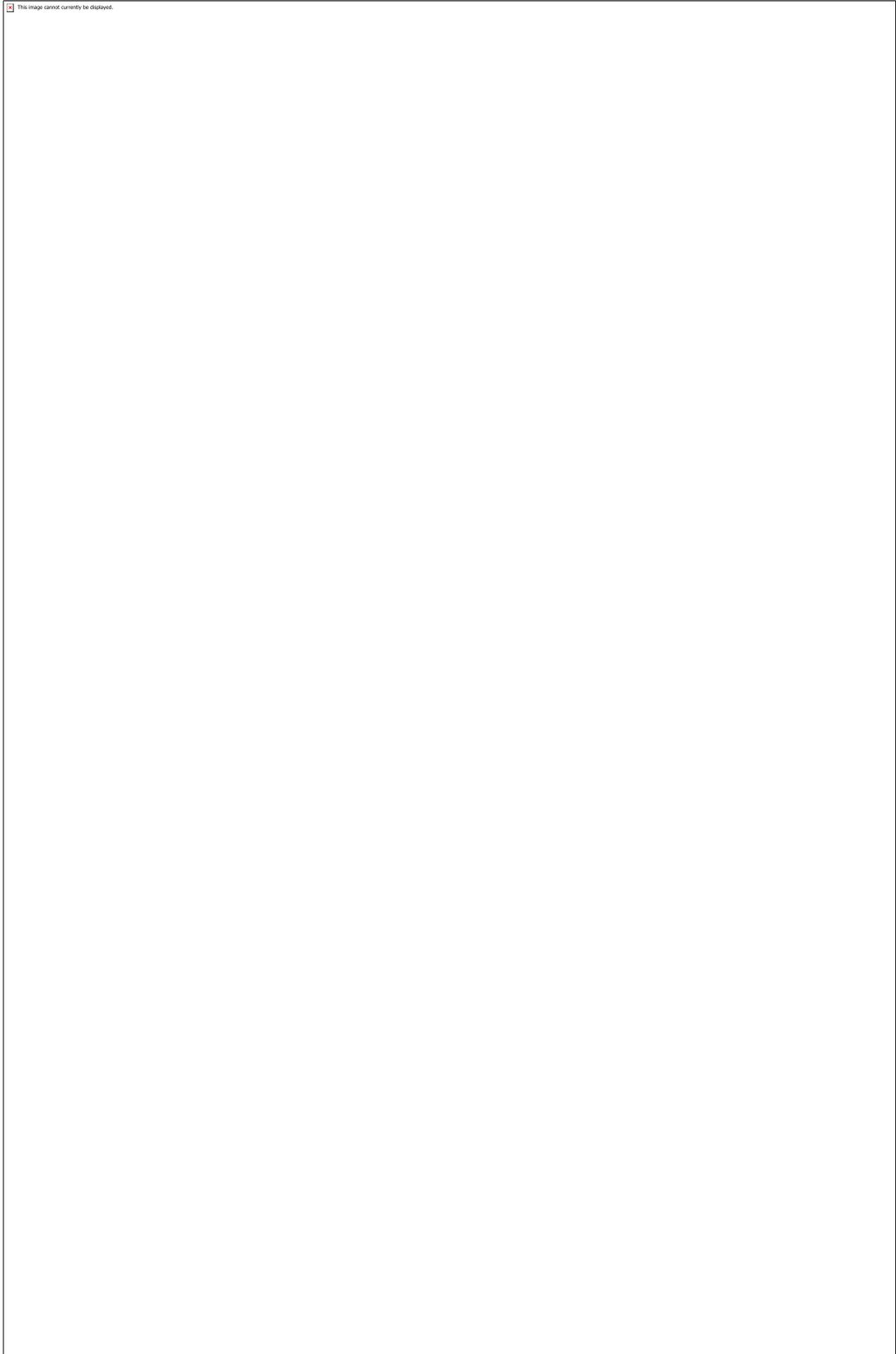
5) \_\_\_\_\_

**Section 11: Recommended action based on the analysis**

Recommended action	Person responsible to take action	Time frame for implementation

## Annex 7: Facility Data Collection form

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## Annex 8: Ethical Approval Letter

Dr Jamila Al Abri  
Liverpool School of Tropical Medicine  
Pembroke Place  
Liverpool  
L3 5QA



Wednesday, 27 July 2016

Dear Dr Al Abri,

### Research Protocol (16-021) 'Maternal "near-miss" review in Oman'

Thank you for your letter of 27 July 2016 providing the necessary in-country approvals for this project. I can confirm that the protocol now has formal ethical approval from the LSTM Research Ethics Committee.

The approval is for a fixed period of three years and will therefore expire on 26 July 2019. The committee may suspend or withdraw ethical approval at any time if appropriate.

Approval is conditional upon:

- Continued adherence to all in-country ethical requirements.
- Notification of all amendments to the protocol for approval before implementation.
- Notification of when the project actually starts.
- Provision of an annual update to the Committee.  
Failure to do so could result in suspension of the study without further notice.
- Reporting of new information relevant to patient safety to the Committee
- Provision of Data Monitoring Committee reports (if applicable) to the Committee

Failure to comply with these requirements is a breach of the LSTM Research Code of Conduct and will result in withdrawal of approval and may lead to disciplinary action. The Committee would also like to receive copies of the final report once the study is completed. Please quote your Ethics Reference number with all correspondence.

Yours sincerely

**Dr Angela Obasi**  
Chair  
LSTM Research Ethics Committee

**Annex 9: Total deliveries, total live births and reported cases of PLTC, MNM and maternal deaths by participating hospitals over a period of 12 months**

Facility code	Facility type	Total women given births	Total Live births	Total PLTC	Total MNM	MD Total	Total reported cases (PLTC, MNM, MD)
1	National	9,702	9,836	196	57	3	256
2	National	5,903	5,974	80	15	5	100
3	Non-MoH	4,342	4,373	101	37	3	141
4	Non-MoH	2,776	2,750	33	14	0	47
5	Non-MoH	588	589	1	2	0	3
6	Governorate	7,248	7,289	65	13	2	80
7	District	1,537	1,533	6	1	1	8
8	Governorate	8,044	8094	246	53	2	301
9	Governorate	1,868	1,870	55	5	0	60
10	Governorate	384	383	6	1	0	7
11	Governorate	4,394	4,414	47	10	0	57
12	Governorate	6,651	6,700	122	17	3	142
13	District	1,694	1,690	19	0	0	19
14	District	707	707	1	0	0	1
15	Governorate	3,566	3,582	103	18	0	121
16	District	2,232	2,227	12	3	1	16
17	Governorate	3,381	3,413	62	29	2	93
18	District	2,912	2,939	108	3	0	111
19	Governorate	51	50	0	0	0	0
20	Governorate	6,953	7,001	133	33	3	169
21	Private	630	627	11	2	0	13
22	Private	2,296	2,295	3	0	0	3
23	Private	587	582	9	0	0	9
	Total	78,446	79,918	1,419	313	25	1,757

## Annex 10: List of reclassified cases

### 1. Re-classified from MNM to PLTC

SN	Description of the case
1	G5P4 with postpartum haemorrhage reported under the criteria of massive blood transfusion. However, she received only four units of PRBC (Packed Red Blood Cell) and did not fulfil other criteria for severe haemorrhage for MNM.
2	G2 P1 had intrauterine foetal death (IUFD) at 25 weeks of gestation. She had induction of labour followed by severe haemorrhage due to retained placenta. She was reported as MNM under the criteria of massive blood transfusion, however she received only four units of PRPC and did not fulfil other MNM criteria
3	G2P1 with placenta previa had LSCS at 36 weeks of gestation, reported as a case of severe postpartum haemorrhage with hysterectomy. Review of case notes by the assessor at hospital level revealed that she had only LSCS without hysterectomy.
4	Primigravida was reported as a case of severe haemorrhage with shock at seven weeks of gestation. Assessor's review revealed that she did not fulfil the definition of shock and did not meet other criteria.
5	G5P3A1 was reported as a case of severe haemorrhage with shock at seven weeks of gestation. Assessor's review revealed that she did not fulfil the definition of shock and did not meet other criteria.
6	G3P2 with severe aortic stenosis, diabetes and hypertension admitted at 40 weeks in labour. She had emlscs and admitted in ICU for close monitoring. Postpartum period was uneventful. She did not fulfil the criteria of MNM with cardiac disease.
7	G2P0A1 at 36 wks with severe pre-eclampsia and HELLP syndrome (BP 170/110 mmHg with blurring of vision and headache) . Assessor's review revealed that she did not fulfil the MNM criteria of hypertensive disorders of pregnancy (normal liver and renal function tests, no thrombocytopenia, and did not develop eclampsia or pulmonary oedema).
8	G7P4 at 36 weeks, was reported as a case of severe postpartum haemorrhage with massive blood transfusion. However, she received only four units of PRBC, three units of fresh frozen plasma and six cryoprecipitates.
9	Para 2 was reported as a case of severe sepsis during the postpartum period. Assessor's review found that she fulfilled the definition of sepsis only (had temperature > 38°C, tachycardia and tachypnea), but did not fulfil the criteria of MNM for severe sepsis.
10	Para 9 reported as a case of cardiomyopathy with pulmonary oedema. Assessor's review found that she did not meet the criteria for pulmonary oedema.
11	G4P2 at 32 weeks with pregnancy induced hypertension was reported as a case of severe HELLP with haemolysis. Assessor's review revealed that she did not satisfy the definition of haemolysis and other MNM criteria of hypertensive disorder of pregnancy
13	G4P3 was reported as a case of IUFD with coagulopathy. Assessor's review found that she did not satisfy the definition disseminated intravascular coagulation (DIC).
14	Primigravida at 39 weeks was admitted in labour with premature rupture of membrane (PROM), had prolonged labour followed by vacuum delivery and severe PPH due to uterine atony, multiple vaginal tears, and vaginal haematoma, evacuated under general anaesthesia. She was reported as MNM with massive blood transfusion, but she received only two units of blood. The assessor commented that there was an underestimation of blood loss with inadequate blood transfusion.
15	G5P4 with previous 4 LSCS at 34 weeks was admitted with abdominal pain. She was diagnosed with IUFD with placenta previa. She had vaginal bleeding after admission and thus taken for LSCS. Intraoperative findings; complete scar dehiscence with lateral extension, foetus and placenta were in the peritoneal cavity. There were 500-600 ml of blood in the peritoneal cavity. She received only two units of blood.
16	Primigravida at 40 weeks was admitted in labour, taken for Emlscs for foetal distress. She had PPH was taken for exploratory laparotomy with bilateral uterine artery ligation and application of B-lynch suture after the failure of conservative measures. She received only four units of PRBS and two units of fresh frozen plasma. She did not fulfil any other MNM criteria.
17	G4P3 with gestational thrombocytopenia. She was admitted at 40 weeks for induction of labour. Her platelet count was $24 \times 10^3$ , which dropped to $5 \times 10^3$ /l. She was transfused with ten units of platelet and had emlscs for foetal distress. She was admitted in ICU for a half-day for monitoring of mild pulmonary oedema.

## 2. Re-classified from PLTC to non-PLTC

SN	Description of the case
1	Primigravida at 39 weeks of gestation was admitted in labour. She was diagnosed with gestational thrombocytopenia with a platelet count of $23 \times 10^3$ /L. She received 12 units of platelet and had spontaneous vaginal deliveries (SVD) with uneventful postpartum period.
2	Primigravida at 35 weeks of gestation was reported as a case of severe pre-eclampsia. However, she was found not satisfying the definition of severe pre-eclampsia. She was admitted for investigation of unexplained proteinuria with normal BP (120/80 mmHg and below). During admission, her 24-hour urine protein was 12gm/24hrs, had uneventful LSCS. Her BP started to raise during the postpartum period with urine protein 2+ with no symptoms or signs of severe pre-eclampsia. She was started on antihypertensive medication and discharged well.
3	G5P2 was admitted at 13 weeks of gestation presented to the emergency room with left leg swelling. She was diagnosed with deep vein thrombosis of common femoral vein and saphenofemoral junction which was treated with anticoagulation and discharged well with no serious complication.
4	Primigravida with gestational thrombocytopenia admitted at 40 weeks of gestation with a platelet count $95 \times 10^3$ /ml. She had induction of labour followed by Emlscs for the failure of progress of labour. She received five units of platelets given during uneventful surgery. Post operation her platelet counts increased and she was discharged well, with no serious complication.
5	G5P3 at 39 weeks of gestation with chorioamnionitis was reported as a case of sepsis. However, she was found not satisfying the definition of sepsis.
6	G4P3 at 30 weeks of gestation was reported as a case of idiopathy thrombocytopenia with no serious complication
7	35 years old P4 had LSCS followed by wound infection without satisfying the definition of sepsis.
8	Primigravida with pre-existing was admitted at five weeks of gestation with chronic headache. She was referred for neurological examination.
9	Primigravida was admitted at 38 weeks of gestation with a breech presentation for LSCS. She was reported as a case of thalassaemia intermedia with iron overload. She had uneventful surgery followed by fever (38 °C) and tachycardia during the postpartum period, but not satisfying the definition of sepsis. She was treated with antibiotic and discharged well.
10	Primigravida at 38 weeks of gestation with Thalassemia intermedia. She had an uneventful pregnancy with no severe complication.
11	G3P2 was admitted at 38 wks. She was reported as a case of Von Willebrand disease type 1. She had no complication during the index pregnancy
12	24 years old primigravida was admitted at 38 weeks of gestation in labour, had a vaginal haematoma but not fulfilling the definition of severe haemorrhage or obstetric trauma.
13	G3P2 was admitted at 38 weeks of gestation with idiopathic thrombocytopenic purpura with no severe complications.
14	G3P2 was admitted in labour reported as a case of sinus bradycardia which was diagnosed with since 2013.
15	G3P2 at 36 weeks of gestation was reported as a case of thrombocytopenia during pregnancy with no severe complications.
16	G4P3 was admitted with mild PIH (BP was > 140/90 mmHg, but < 160/110 mmHg). She was found to have high creatine level of 292. Review of patient medical file reveals that she had a high creatine level of 273 since last pregnancy in 2013. She was diagnosed as a chronic renal disease with no acute exacerbation.
17	G2P1 at 41 weeks of gestation was reported as a case of severe pre-eclampsia. However, she was found not satisfying the definition of severe pre-eclampsia.
18	Primigravida was admitted at 35 weeks of gestation with an acute abdomen. She was diagnosed as a case of rupture adnexal mass with peritoneal irritation. She was not in shock and not satisfying the definition of severe haemorrhage or sepsis. She had uneventful laparotomy with LSCS.
19	23 years old admitted at 37 weeks of gestation in labour with a history of fever and cough of three-days duration. On admission she was afebrile (37°C). She had Emlscs for foetal distress. Post-operation chest x-ray showed right middle zone pneumonia. Complete blood count was normal. She was started on antibiotic and antiviral medication. She remained afebrile and discharged well on day four post-operation.
20	G4P2 was admitted in labour. She was reported as a case with chronic anaemia, but not satisfying the definition of severe anaemia. She was transfused with one unit of blood.

SN	Description of the case
21	G3P2 was admitted in labour. She was reported as a case of thrombocytopenia with no severe complication.
22	G8P6 at five weeks of gestation was admitted with rupture ectopic pregnancy, but not satisfying the definition of severe haemorrhage
23	33 years old P2 was reported as a case of a perineal tear without having a severe haemorrhage.
24	P2 was reported as a case of a perineal tear without having a severe haemorrhage.
25	G5P2 at 35 weeks of gestation was reported as a case of severe pre-eclampsia. She was admitted with PIH and mild headache. She was found not satisfying the definition of severe pre-eclampsia.
26	G2P1 was admitted at 35 weeks of gestation with PIH. She was found not satisfying the definition of severe pre-eclampsia (BP < 160/110 mmHg with no symptoms and signs of severe pre-eclampsia).
27	P1 with 3 <sup>rd</sup> degree perineal tear without having a severe haemorrhage.
28	P1 with 3 <sup>rd</sup> degree perineal tear without having a severe haemorrhage.
29	P2 with 3 <sup>rd</sup> degree perineal tear without having a severe haemorrhage.
30	P1 with 3 <sup>rd</sup> degree perineal tear without having a severe haemorrhage.
31	P1 with 3 <sup>rd</sup> degree perineal tear without having a severe haemorrhage.
32	P1 with 4 <sup>th</sup> degree perineal tear without having a severe haemorrhage.
33	G3P2 at 38 weeks of gestation was reported as a case of hepatitis B, Ag positive and idiopathic thrombocytopenia, without having a severe complication.
34	P1 was reported as a case of sepsis following LSCS. She had an increase in the white cell count up to $29 \times 10^3/l$ . However, temperature was less than 38°C with no other signs of sepsis.
35	G4P3 was admitted at 40 weeks of gestation in labour, noted to have impaired liver function tests with a low platelet count. Her BP readings during admission was less than 140/90 mmHg. Review of her medical file revealed this is a chronic condition with no acute exacerbation.
36	Primigravida was admitted at 40 weeks of gestation with fever (38.6 C), pulse rate 116/minutes and RR 20/minutes. She was found to have upper respiratory tract infection which was treated with an antibiotic. She did not satisfy the definition of sepsis.
37	G2P1 at 38 weeks of gestation was admitted in labour. She had LSCS for non-progress of labour followed by an increase in WBC from $18 \times 10^9/l$ to $21 \times 10^9/l$ . A diagnosis of chest infection was made which was treated and responded to antibiotic. She was not fulfilling the definition of sepsis (temperature less than 38°C and no signs of sepsis).
38	G4P3 had PIH (BP = 145/100 mmHg) but did not satisfy the definition of severe pre-eclampsia or HELLP syndrome.
39	P1 was reported as a case of a perineal tear without having a severe haemorrhage or other severe complications.
40	25 years old, had rupture of ectopic pregnancy without having a severe haemorrhage.
41	P3 was reported as a case of a perineal tear without having a severe haemorrhage or other PLTC condition.

**Annex 11: list of cases which were reported in group of other underlying causes and which were re-classified into different groups.**

<b>Type of case</b>	<b>Description of the case</b>	<b>No. cases</b>
<b>PLTC cases</b>	Arrhythmia (supraventricular tachycardia) required admission to a high dependency unit/ ICU for monitoring. Re-classified to the group of non-obstetric complications (cardiac disorder)	2
	Myasthenia gravis crisis. Re-classified to the group of non-obstetric complications (central nervous system disorder)	1
	Spinal cord abscess with sepsis, re-classified to the group of non-obstetric complication (infection)	1
	Symptomatic severe anaemia (Hb ≤ 6 g/dl), re-classified to the group of non-obstetric complications (haematological disorders)	6
	Severe gestational thrombocytopenia required massive platelet transfusion, followed by developing pulmonary oedema and admission to ICU. Re-classified to the group of non-obstetric complications (haematological disorders)	1
<b>MNM</b>	Bladder injury with acute renal failure during LSCS. Re-classified to the group of other obstetric complications (trauma to bladder and other pelvic organs)	1
	Unmatched blood transfusion resulted in organ failure. Reclassified to the group of un-anticipated complications of management	1
	Wernicke encephalopathy. Re-classified to other obstetric complications	1
<b>Maternal deaths</b>	Death due to brain neoplasm. Re-classified to non-obstetric complications (neoplasm)	1

## Annex 12: Causes of PLTC, MNM and maternal deaths

Specific cause	PLTC (1,149)	MNM (313)	MD (25)	Total (1,757)
% of cases (No. times identified)				
<b>Group 1: Pregnancy with abortive outcome</b>				
Ruptured ectopic pregnancy	3.1(44)	2.2 (7)	-	2.9 (51)
Miscarriage with excessive bleeding/sepsis	2.5 (36)	2.9 (9)	4.0 (1)	2.5 (44)
Abortion with excessive bleeding/sepsis	18 (1.3)	0.6 (2)	-	1.1 (20)
Molar pregnancy	0.1 (2)	-	-	0.1 (2)
No specified	0.1 (1)	-	-	0.1 (1)
Severe haemorrhage	7.1(101)	4.5(14)	-	6.4 (113)
Sepsis	-	1.6 (5)	-	0.3 (5)
Massive PE	-	-	4.0 (1)	0.1 (1)
<b>Total</b>	<b>7.1 (101)</b>	<b>5.8(18)</b>	<b>4.0 (1)</b>	<b>6.8 (120)</b>
<b>Group 2: Hypertensive disorders of pregnancy</b>				
Severe preeclampsia	27.7 (393)	21.7 (68)	0.8 (2)	26.4 (463)
Eclampsia	-	19.5 (61)	4.0 (1)	3.5 (62)
HELLP syndrome	0.1 (1)	11.5 (36)	-	2.1 (37)
<b>Total</b>	<b>393 (27.7)</b>	<b>44.1 (138)</b>	<b>12.0 (3)</b>	<b>30.4 (534)</b>
<b>Group 3: Obstetric haemorrhage</b>				
Antepartum haemorrhage	5.7 (56)	3.5 (11)	9.1 (1)	6.0 (6.9)
Intrapartum haemorrhage	31.9 (312)	11.8 (37)	18.2 (2)	30.5 (352)
Postpartum haemorrhage	39.1 (380)	11.2 (35)	-	6.3 (415)
<b>Total</b>	<b>51.0 (723)</b>	<b>22.7 (71)</b>	<b>12.0 (3)</b>	<b>45.4 (797)</b>
<b>Group 4: Pregnancy-related infection</b>				
Puerperal sepsis	2.0 (28)	1.6 (5)	-	1.9 (33)
Infection of genitourinary tract	1.1 (15)	0.3 (1)	-	0.9 (16)
Chorioamnionitis	1.1 (15)	-	-	0.9 (15)
<b>Total</b>	<b>3.0 (56)</b>	<b>1.9 (6)</b>	<b>-</b>	<b>3.5 (62)</b>
<b>Group 5: Other obstetric complications</b>				
<b>Obstetric trauma</b>				
Obstetric trauma to other pelvic organs	2.6 (37)	1.3 (4)	-	2.3 (41)
Postpartum inversion of uterus	0.2 (3)	-	-	0.2 (3)
<b>Subtotal</b>	<b>2.8 (40)</b>	<b>1.3 (4)</b>	<b>-</b>	<b>2.5 (44)</b>
<b>Obstetric embolism</b>				
Massive PE	-	1.3 (4)	12.0 (3)	0.4 (7)
AFI	-	0.3 (1)	4.0 (1.0)	0.1 (2)
<b>Subtotal</b>	<b>-</b>	<b>1.6 (5)</b>	<b>16.0 (4)</b>	<b>0.5 (9)</b>
Peripartum cardiomyopathy	0.2 (3)	1.9 (6)	-	0.5 (9)
<b>Intentional self-harm</b>				
Intentional self-harm	0.1 (1)	-	-	1 (0.1)
Wernicke's encephalopathy	-	0.3 (1)	-	1 (0.1)
<b>Total</b>	<b>3.1 (44)</b>	<b>5.1 (16)</b>	<b>16.0 (4)</b>	<b>64 (3.6)</b>
<b>Group 6: Un-anticipated complications of management</b>				
<b>1. Complication of anaesthesia</b>				
Succinylcholine apnoea	5 (0.4)	1.6 (5)	-	0.5 (10)
Cerebral anoxia	0.1 (1)	1.3 (4)	-	0.3 (5)
Aspiration pneumonitis	0.1 (1)	0.3 (1)	-	0.1 (2)
Severe headache	0.1 (1)	-	-	0.1 (1)
Shortness of breathing and bronchospasm	0.1 (1)	-	-	0.1 (1)
<b>2. Transfusion of unmatched blood</b>				
<b>Total</b>	<b>-</b>	<b>0.3 (1)</b>	<b>-</b>	<b>0.1 (1)</b>
<b>Total</b>	<b>5 (0.4)</b>	<b>1.9 (6)</b>	<b>-</b>	<b>0.6 (11)</b>
<b>Group 7: Non-obstetric complications</b>				
<b>Haematological disorders</b>				

Sickle cell disease with crisis	1.3 (18)	9.6 (30)	16.0 (4)	3.0 (52)
TTP	-	0.3 (1)	-	0.1 (1)
Severe anaemia	0.4 (6)	-	-	0.3 (6)
Severe gestational thrombocytopenia	0.1 (1)	-	-	0.1 (1)
<b>Subtotal</b>	<b>1.8 (25)</b>	<b>9.9 (31)</b>	<b>16.0 (4)</b>	<b>3.4 (60)</b>
<b>Cardiac disorders</b>				
Cardiomyopathy	0.2 (3)	2.2 (7)	-	0.6 (10)
Acute severe HTN	2 (0.2)	-	4.0 (1)	0.2 (3)
Acute atrial fibrillation	0.1 (1)	0.3 (1)	4.0 (1)	0.2 (3)
Pulmonary HTN	0.1 (1)	-	4.0 (1)	0.1 (2)
Severe valvular heart disease	0.1 (1)	0.3 (1)	-	0.1 (2)
Arrhythmia	0.2 (2)	-	-	0.1 (2)
<b>Subtotal</b>	<b>0.7 (10)</b>	<b>2.9 (9)</b>	<b>8.0 (2)</b>	<b>1.2 (21)</b>
<b>Infection</b>				
Sepsis	0.7 (10)	0.3 (1)	4.0 (1)	0.7 (12)
Severe pneumonia	0.5 (7)	0.6 (2)	4.0 (1)	0.6 (10)
Spinal cord abscess	0.1 (1)	-	-	0.1 (1)
<b>Subtotal</b>	<b>1.2 (17)</b>	<b>0.3 (1)</b>	<b>8.0 (2)</b>	<b>1.3 (22)</b>
<b>Central nervous system disorders</b>				
Epilepsy	0.8 (11)	0.3 (1)	-	0.7 (14)
Intracranial and subarachnoid haemorrhage	-	0.6 (2)	4.0 (1)	0.2 (3)
Convulsion of unknown origin	0.2 (3)	-	-	0.2 (3)
Myasthenia gravis crisis	0.1 (1)	-	-	0.1 (1)
<b>Subtotal</b>	<b>1.1 (15)</b>	<b>1.6 (5)</b>	<b>4.0 (1)</b>	<b>1.2 (21)</b>
<b>Respiratory disorders</b>				
Severe asthma	0.2 (3)	0.3 (1)	-	0.2 (4)
Pulmonary oedema	-	0.3 (1)	-	0.2 (3)
Acute respiratory distress syndrome	0.1 (1)	2 (0.6)	4.0 (1)	0.2 (4)
<b>Subtotal</b>	<b>0.3 (4)</b>	<b>1.9 (6)</b>	<b>4.0 (1)</b>	<b>0.6 (11)</b>
Endocrine -DKA	0.4 (6)	2 (0.6)	-	0.5 (8)
<b>Connective tissue disorder</b>				
Flare of systematic lupus erythematosus	0.1 (2)	-	4.0 (1)	0.2 (3)
Antiphospholipid syndrome	0.2 (3)	-	-	0.2 (3)
<b>Subtotal</b>	<b>0.4 (5)</b>	<b>-</b>	<b>4.0 (1)</b>	<b>0.3 (6)</b>
<b>GIT</b>				
Non-pregnancy related liver disease	0.2 (3)	-	-	0.2 (3)
Acute pancreatitis	0.1 (1)	-	-	0.1 (1)
Acute cholecystitis	0.1 (2)	-	-	0.1 (2)
<b>Subtotal</b>	<b>0.4 (6)</b>	<b>-</b>	<b>-</b>	<b>0.3 (6)</b>
GUT disorders (ARF)	-	0.3 (1)	4.0 (1)	0.1 (2)
Neoplasm	-	-	4.0 (1)	0.1 (1)
<b>Total</b>	<b>6.2 (88)</b>	<b>17.9 (56)</b>	<b>48.0 (12)</b>	<b>8.9 (156)</b>
<b>Group 8: Other severe complications</b>				
Brain tumour	-	-	4.0 (1)	0.1 (1)
Severe ovarian hyperstimulation syndrome	0.3 (4)	-	-	0.2 (4)
Atypical lymphoproliferative disorder	0.1 (1)	-	-	0.1 (1)
Cardiac arrest during LSCS with an unknown cause	-	0.3 (1)	-	0.1 (1)
Intrauterine death with deranged coagulation	0.1 (1)	-	-	0.1 (1)
Maternal death on arrival with an unknown cause	-	-	0.8 (2)	0.1 (1)
Ovarian plexus bleeding	-	0.3 (1)	-	0.1 (1)
Ovarian vein thrombosis	0.1 (1)	-	-	0.1 (1)
Rectus sheath haematoma, unspecified	0.1 (1)	-	-	0.1 (1)

<b>cause</b>				
<b>Uterine scar dehiscence</b>	0.1 (1)	-	-	0.1 (1)
<b>Total</b>	0.6 (9)	0.6 (2)	0.8 (2)	0.7 (13)

**Annex 13: Most likely underlying cause of maternal near-miss as assigned by reviewers at the hospital level**

Group/ specific cause	Frequency	Within the group	% of the total of 313 MNM events
Pregnancy with abortive outcome	17		5.4
Ruptured ectopic pregnancy	7	41.2	2.2
Miscarriage complicated by sepsis	3	17.6	1.0
Miscarriage complicated by haemorrhage	2	17.6	1.0
Septic abortion	2	11.8	0.6
Post-miscarriage sepsis with peripartum cardiomyopathy	1	5.9	0.3
Retained product of conception	1	5.9	0.3
Hypertensive disorders of pregnancy	129		41.2
Severe pre-eclampsia (includes 5 cases with pulmonary oedema, one case with acute heart failure, one with obstetric haemorrhage)	42	32.6	13.4
Eclampsia (including one case with subarachnoid haemorrhage and one case with aspiration pneumonia and posterior reversible encephalopathy syndrome, and one case with cortical sinus venous thrombosis and brain haemorrhage (parietal lobe))	28	66.7	8.9
Eclampsia with severe pre-eclampsia	21	16.3	6.7
HELLP syndrome with severe pre-eclampsia (include one case with acute renal failure)	13	10.1	4.2
HELLP syndrome (include one case with placental abruption)	11	8.5	3.5
Pregnancy-induced hypertension (one with abnormal liver enzymes and one with proteinuria)	8	6.2	2.6
Eclampsia with HELLP syndrome	2	1.6	0.6
Impending eclampsia with severe pre-eclampsia and HELLP	1	0.8	0.3
Hypertensive disorder with haemolysis and deranged liver function tests	1	0.8	0.3
Unspecified	2	1.6	0.6
Obstetric haemorrhage	73		23.3
Morbidly adherent placenta (including one case with an atonic uterus and one with bladder injury)	23	31.5	7.3
Placental abruption	7	9.6	2.2
Placenta previa (including one with abnormal pelvic mass)	6	8.2	1.9
Cervical tear	3	4.1	1.0
Vaginal tear	3	4.1	1.0
Atonic uterus and traumatic postpartum haemorrhage	3	4.1	1.0
Uterine rupture (one with bladder injury)	3	4.1	1.0
Obstetric trauma (traumatic instrumental delivery)	3	4.1	1.0
Uterine atony	2	2.7	0.6
Retained placenta and retained product of conception	2	2.7	0.6
Ruptured uterine artery during caesarean section	1	1.4	0.3
Surgical haemorrhage	1	1.4	0.3
Uterine scar dehiscence	1	1.4	0.3
Perineal tears	1	1.4	0.3
Postoperative pelvic haematoma	1	1.4	0.3
Caesarean hysterectomy	1	1.4	0.3
Em LSCS for breech presentation in active labour	1	1.4	0.3
Large vessels united on the previous uterine scar	1	1.4	0.3
Obstructed labour	1	1.4	0.3
Presence of large fibroids in the LSCS incision site	1	1.4	0.3

Group/ specific cause	Frequency	Within the group	% of the total of 313 MNM events
Secondary postpartum haemorrhage due to an anticoagulant drug	1	1.4	0.3
Secondary postpartum haemorrhage due to endometritis	1	1.4	0.3
Secondary postpartum haemorrhage, unspecified	1	1.4	0.3
Severe intrapartum hypertension with uterine atony	1	1.4	0.3
Antepartum haemorrhage, unspecified	1	1.4	0.3
Postpartum haemorrhage, unspecified	1	1.4	0.3
Unspecified	2	2.7	0.6
Pregnancy-related infection	8		2.6
Sepsis, unspecified	2	25.0	0.6
Infected pelvic hematoma with peritonitis and pleural effusion following LSCS	1	12.5	0.3
Infection complicating caesarean hysterectomy	1	12.5	0.3
Puerperal sepsis due to retained product of conception	1	12.5	0.3
Sepsis due to premature rupture of membrane (PROM)	1	12.5	0.3
Sepsis-induced myocarditis	1	12.5	0.3
Syphilis with heart failure	1	12.5	0.3
Other obstetric complications	20		6.4
Peripartum cardiomyopathy (including one with chronic hypertension)	9	45.0	2.9
Pulmonary embolism	4	20.0	1.3
Amniotic fluid embolism	1	5.0	0.3
Peripartum cardiomyopathy and fluid overload following postpartum haemorrhage	1	5.0	0.3
Obstetric trauma to pelvic organs following obstructed labour	1	5.0	0.3
Sigmoid perforation with faecal peritonitis following LSCS	1	5.0	0.3
Uterine rupture with bladder injury	1	5.0	0.3
Uterine torsion	1	5.0	0.3
Wernicke's Encephalopathy	1	5.0	0.3
Un-anticipated complications of management	9		2.9
Complications of anaesthetic drugs	5	55.6	1.6
Pulmonary oedema due to volume overload	2	22.2	0.6
Fluid overload with cardiomyopathy	1	11.1	0.3
Mismatched blood transfusion	1	11.1	0.3

Group/ specific cause	Frequency	Within the group	% of the total of 313 MNM events
<b>Non-obstetric complications</b>	52		16.6
Sickle cell disease crisis (including one case with pneumonia and one with parvovirus infection)	30	57.7	9.6
Epilepsy	4	7.7	1.3
Diabetes Mellitus (including two cases with diabetes ketoacidosis)	3	5.8	1.0
Cardiac disease (including two cases with mitral valve stenosis)	3	5.8	1.0
Acute exacerbation of bronchial asthma	1	1.9	0.3
Acute pulmonary oedema due to anaemia	1	1.9	0.3
Chronic kidney disease	1	1.9	0.3
Myasthenia gravis	1	1.9	0.3
Obstructive jaundice due to gallstone	1	1.9	0.3
Ovarian plexus bleeding	1	1.9	0.3
Pneumonia	1	1.9	0.3
Systemic lupus erythematosus (SLE)	1	1.9	0.3
Severe hypertension and SLE	1	1.9	0.3
Sickle cell disease and SLE	1	1.9	0.3
Stroke	1	1.9	0.3
Thrombotic thrombocytopenic purpura	1	1.9	0.3
Unspecified ICD-MM group of cause	5		1.6
Cardiac arrest with unknown cause	1	20	0.3
Unspecified	4	80	1.3

**Annex 14: Most likely underlying cause of MNM assigned by reviewers  
at the regional level**

Group/ specific cause	Frequency	% Within the group	% of the 290 MNM events
Pregnancy with abortive outcome	12		4.1
Septic abortion	3	25.0	1.0
Sepsis	1	8.3	0.3
Rupture ectopic pregnancy	1	8.3	0.3
Missed abortion complicated by excessive bleeding	1	8.3	0.3
Missed abortion, unspecified	1	8.3	0.3
Induced abortion	1	8.3	0.3
Incomplete abortion complicated by excessive bleeding	1	8.3	0.3
Bleeding from scar pregnancy	1	8.3	0.3
Unspecified	2	16.7	0.7
Hypertensive disorder of pregnancy	125		43.1
Eclampsia	42	33.3	14.5
Severe pre-eclampsia (including 5 cases with pulmonary oedema)	31	24.6	10.7
HELLP syndrome	21	16.7	7.2
Severe pre-eclampsia with HELLP syndrome	7	5.6	2.4
Pregnancy-induced hypertension, unspecified	3	2.4	1.0
Chronic hypertension complicated by pulmonary oedema	1	0.8	0.3
Severe preeclampsia with eclampsia	1	0.8	0.3
Eclampsia with HELLP	1	0.8	0.3
Severe hypertension complicated by pulmonary oedema	1	0.8	0.3
Pulmonary oedema	1	0.8	0.3
Unspecified	16	12.7	5.5
Obstetric haemorrhage	74		25.5
Morbidly adherent placenta	9	12.2	3.1
Placenta previa	6	8.1	2.1
Abruptio placenta	6	8.1	2.1
Obstetric trauma	4	5.4	1.4
Intraoperative postpartum haemorrhage	4	5.4	1.4
Atonic uterus	3	4.1	1.0
Pelvic haematoma	3	4.1	1.0
Uterine rupture	2	2.7	0.7
Vaginal tears (one with injury to the uterine artery)	2	2.7	0.7
Retained placenta	1	1.4	0.3

Group/ specific cause	Frequency	% Within the group	% of the 290 MNM events
Traumatic and atonic postpartum haemorrhage	1	1.4	0.3
Intrapartum haemorrhage with bladder injury	1	1.4	0.3
Antepartum haemorrhage with coagulation defect	1	1.4	0.3
Ruptured ectopic pregnancy	1	1.4	0.3
Secondary post-partum haemorrhage	1	1.4	0.3
Unspecified	10	13.5	3.4
<b>Pregnancy-related infections</b>	<b>6</b>		<b>2.1</b>
Sepsis, unspecified	2	33.3	0.7
Puerperal sepsis	2	33.3	0.7
Puerperal sepsis haemolytic uremic syndrome	1	16.7	0.3
Syphilis	1	16.7	0.3
<b>Other obstetric complications</b>	<b>15</b>		<b>5.2</b>
Peripartum cardiomyopathy	3	20.0	1.0
Uterine rupture with injury to other pelvic organs	2	13.3	0.7
Amniotic fluid embolism	1	6.7	0.3
Embolism, unspecified	1	6.7	0.3
Pulmonary embolism	1	6.7	0.3
Placenta previa accreta	1	6.7	0.3
Obstetric trauma to pelvic organs with sepsis	1	6.7	0.3
Uterine torsion	1	6.7	0.3
Wernicke's encephalopathy	1	6.7	0.3
Unspecified	1	6.7	0.3
Sickle cell disease	1	6.7	0.3
Postpartum eclampsia	1	6.7	0.3
<b>Un-anticipated complications of management</b>	<b>6</b>		<b>2.1</b>
Anaesthesia complication, unspecified	1	16.7	0.3
Cardiac arrest following spinal anaesthesia for an unknown reason	1	16.7	0.3
Succinylcholine apnoea	1	16.7	0.3
Cerebral anoxia due to anaesthesia	1	16.7	0.3
Aspiration pneumonia	1	16.7	0.3
Unspecified	1	16.7	0.3
<b>Non-obstetric complications</b>	<b>51</b>		<b>17.6</b>
Sickle cell disease	24	47.1	8.3
Peripartum cardiomyopathy	4	7.8	1.4
Cardiac disease (include one case of mitral stenosis and one heart failure)	3	5.9	1.0

Group/ specific cause	Frequency	% Within the group	% of the 290 MNM events
Anaemia complicating pregnancy childbirth and puerperium	2	3.9	0.7
Diabetes Mellitus with acute respiratory distress syndrome	1	2.0	0.3
Bronchial asthma	1	2.0	0.3
Cavernous haemangioma	1	2.0	0.3
Common bile duct obstruction with liver impairment	1	2.0	0.3
Epilepsy	1	2.0	0.3
SLE	1	2.0	0.3
TTP with renal impairment and hypertension	1	2.0	0.3
Pulmonary oedema	1	2.0	0.3
Pulmonary embolism	1	2.0	0.3
Sepsis	1	2.0	0.3
Non-obstetric haemorrhage shock	1	2.0	0.3
Unspecified	7	13.7	2.4
Unspecified ICD-MM group of causes	1		0.3

**Annex 15: Most likely underlying cause of MNM assigned by reviewers  
at the national level**

Group/ specific cause	Frequency	% Within the group	% of the 156 MNM events
Pregnancy with abortive outcome	4		2.6
Induced (illegal) abortion complicated by sepsis	1	25.0	0.6
Incomplete abortion complicated by excessive bleeding	1	25.0	0.6
Ruptured ectopic pregnancy	1	25.0	0.6
Sepsis	1	25.0	0.6
Hypertensive disorders of pregnancy	65		41.7
Eclampsia	24	36.9	15.4
HELLP syndrome	9	13.8	5.8
Severe pre-eclampsia (including 6 cases with pulmonary oedema)	15	23.1	9.6
Severe pre-eclampsia with HELLP syndrome	10	15.4	6.4
Eclampsia with HELLP syndrome	3	4.6	1.9
Severe pre-eclampsia with eclampsia	1	1.5	0.6
Severe pregnancy-induced hypertension with pulmonary oedema	1	1.5	0.6
Pulmonary oedema	1	1.5	0.6
Hypertensive disorder complicated by abnormal liver enzymes and haemolysis	1	1.5	0.6
Obstetric haemorrhage	43		27.6
Morbidly adherent placenta (one with uterine atony)	7	16.3	4.5
Abruption placenta	4	9.3	2.6
Obstetric trauma	4	9.3	2.6
Postpartum haemorrhage	4	9.3	2.6
Uterine atony	3	7.0	1.9
Traumatic and atonic postpartum haemorrhage	3	7.0	1.9
Placenta previa	2	4.7	1.3
Uterine rupture (one with bladder injury)	2	4.7	1.3
Haemorrhage with caesarean section	2	4.7	1.3
Postpartum haemorrhage with vaginal and left broad ligament haematoma	1	2.3	0.6
Intrapartum and postpartum haemorrhage with hysterectomy	1	2.3	0.6
Postpartum haemorrhage with hysterectomy	1	2.3	0.6
Secondary postpartum haemorrhage due to over-anticoagulation with warfarin	1	2.3	0.6

Group/ specific cause	Frequency	% Within the group	% of the 156 MNM events
Secondary severe postpartum haemorrhage	1	2.3	0.6
Rectus muscle haematoma	1	2.3	0.6
Ruptured ectopic pregnancy	1	2.3	0.6
Intrapartum haemorrhage	1	2.3	0.6
Unspecified	4	9.3	2.6
Pregnancy-related infection	2		1.3
Pelvic collection with sepsis	1	50.0	0.6
Puerperal Sepsis with haemolytic uremic syndrome	1	50.0	0.6
Other obstetric complication	7		4.5
Peripartum cardiomyopathy	2	28.6	1.3
Pulmonary embolism	2	28.6	1.3
Uterine rupture with injury to other pelvic organs	1	14.3	0.6
Wernicke's encephalopathy	1	14.3	0.6
Post LSCS sepsis and bowel injury	1	14.3	0.6
Un-anticipated complications of management	6		3.8
Complications of anaesthesia- succinylcholine apnea	3	50.0	1.9
Cardiac arrest following spinal anaesthesia	1	16.7	0.6
Mismatched blood transfusion full haemolysis with acute lung injury	1	16.7	0.6
Pulmonary oedema due to volume overload	1	16.7	0.6
Non-obstetric complication	29		18.6
Sickle cell disease	16	55.2	10.3
Cardiomyopathy with acute atrial fibrillation	1	3.4	0.6
Mitral valve stenosis	1	3.4	0.6
Aneurysmal subarachnoid haemorrhage	1	3.4	0.6
Chronic renal impairment	1	3.4	0.6
Diabetic ketoacidosis	1	3.4	0.6
Epilepsy	1	3.4	0.6
Anaemia complicated by heart failure	1	3.4	0.6
Myasthenia Gravis complicated by pneumonia	1	3.4	0.6
Systemic lupus erythematosus	1	3.4	0.6
Peripartum cardiomyopathy	3	10.3	1.9
Unspecified	1	3.4	0.6

**Annex 16: Most likely underlying cause of MNM assigned by the International Expert Panel**

Group/ specific cause		% within the group	% of 156 MNM events
Pregnancy with abortive outcome	4	4	2.6
Ruptured ectopic pregnancy	1	1	25.0
Incomplete miscarriage complicated by severe infection	1	1	25.0
Incomplete/septic abortion in unplanned pregnancy	1	1	25.0
Unspecified	1	1	25.0
<b>Hypertensive disorders of pregnancy</b>	<b>65</b>		<b>41.0</b>
Eclampsia (including one with PRES)	15	23.4	9.6
Severe pre-eclampsia	11	17.2	7.1
Eclampsia and severe pre-eclampsia	5	7.8	3.2
Severe pre-eclampsia and HELLP syndrome (include one with abruptio placenta)	12	18.8	7.7
HELLP syndrome (include one partial and one with acute renal failure)	4	6.3	2.6
SLE and anti-phospholipid AB syndrome	2	3.1	1.3
Eclampsia and HELLP syndrome	2	3.1	1.3
Pregnancy-induced hypertension	2	3.1	1.3
Chronic hypertension with peripartum cardiomyopathy	1	1.6	0.6
Concentric Left Ventricular Hypertrophy secondary to Hypertension	1	1.6	0.6
Essential (chronic) hypertension	1	1.6	0.6
Intrapartum pregnancy-induced hypertension with haemorrhage	1	1.6	0.6
Low platelets with risk of HELLP syndrome	1	1.6	0.6
Postnatal hypertension with altered renal function	1	1.6	0.6
Pregnancy-induced hypertension with elevated liver enzymes, haemolysis and elevated creatinine	1	1.6	0.6
Pulmonary oedema with pregnancy-induced hypertension	1	1.6	0.6
Unspecified	4	6.3	2.6
<b>Obstetric haemorrhage</b>	<b>40</b>		<b>25.6</b>
Morbidly adherent placenta	8	20.0	5.1
Placenta previa	6	15.0	3.8
Intraoperative trauma (including one case with inadequately ligated uterine arteries)	6	15.0	3.8
Atonic uterus	1	2.5	0.6
Cervical tear and atonic uterus	1	2.5	0.6
Abruptio placenta	2	5.0	1.3

Group/ specific cause		% within the group	% of 156 MNM events
Postpartum haemorrhage	2	5.0	1.3
Placenta abruption with severe pre-eclampsia	1	2.5	0.6
Bleeding following elective LSCS and removal of fibroid	1	2.5	0.6
Delayed PPH related to endometritis, and possibly retained products of conception	1	2.5	0.6
Trauma to genital tract resulting in vaginal haematoma and broad ligament haematoma	1	2.5	0.6
Uterine atony, vascular bleeding and broad ligament haematoma	1	2.5	0.6
Ruptured ectopic pregnancy	1	2.5	0.6
Secondary postpartum haemorrhage	1	2.5	0.6
Unspecified	7	17.5	4.5
Pregnancy-related infection	1		0.6
Unspecified	1	100.0	0.6
Other obstetric complications	13		8.3
Uterine rupture (including one with bladder injury)	3	23.1	1.9
Peripartum cardiomyopathy	2	15.4	1.3
Pulmonary embolism	2	15.4	1.3
Peripartum cardiomyopathy with fluid overload	1	7.7	0.6
Bowel perforation following caesarean	1	7.7	0.6
Gestational thrombocytopenia with pulmonary oedema	1	7.7	0.6
Haemolytic uraemic syndrome	1	7.7	0.6
HELLP syndrome, possible acute fatty liver	1	7.7	0.6
Hyperemesis gravidarum leading to Wernicke's encephalopathy	1	7.7	0.6
Un-anticipated complication of management	5		3.2
Artificial membrane rupture caused cord prolapse and severe obstetric haemorrhage	1	7.7	0.6
Cardiac arrest during CS under spinal anaesthesia with midazolam sedation	1	7.7	0.6
Cardiac condition predisposing to pulmonary oedema	1	7.7	0.6
Life-threatening transfusion reaction after receiving ABO incompatible blood	1	7.7	0.6
Prolonged apnoea after general anaesthesia	1	20.0	0.6
Non-obstetric complications	28		17.9
Sickle cell disease with crisis	14	51.9	9.0
Complications of anaesthesia	2	7.4	1.3
Sickle cell disease with peripartum cardiomyopathy	1	3.7	0.6
Sickle cell disease and SLE with severe pre-eclampsia and vitamin B12 deficiency	1	3.7	0.6

<b>Group/ specific cause</b>		<b>% within the group</b>	<b>% of 156 MNM events</b>
<b>Uncontrolled epileptic seizures</b>	1	3.7	0.6
<b>Ruptured cerebral aneurysm – subarachnoid haemorrhage</b>	1	3.7	0.6
<b>Left MCA thrombus led to right-sided CVA</b>	1	3.7	0.6
<b>Pulmonary oedema secondary to co-existent heart disease</b>	1	3.7	0.6
<b>Convulsion related to hypocalcaemia and hypoparathyroidism</b>	1	3.7	0.6
<b>Acute postpartum pulmonary oedema</b>	1	3.7	0.6
<b>Acute respiratory failure complicating myasthenia gravis</b>	1	3.7	0.6
<b>Bleeding from left adnexa</b>	1	3.7	0.6
<b>Chronic renal disease</b>	1	3.7	0.6
<b>Insulin-dependent diabetes mellitus with diabetic keto-acidosis</b>	1	51.9	9.0

### Annex 17: Contributory conditions identified by hospital reviewers

Identified contributory conditions	For total MNM events (313) % (n)	For pregnancy with abortive outcome (17) % (n)	For hypertensive disorders of pregnancy (129) % (n)	For obstetric haemorrhage (72) % (n)	For pregnancy-related infection (8) % (n)	For other obstetric complications (19) % (n)	For un-anticipated complications of management (9) % (n)	For non-obstetric complications (54) % (n)	For unspecified causes (5) % (n)
	68.7 (215)	58.8 (10)	53.5 (69)	87.5 (63)	75.0(6)	68.4 (13)	88.9 (8)	79.6 (43)	60.0 (3)
<b>Maternal</b>	50.2 (157)	47.1 (8)	33.0 (43)	76.4 (55)	50.0 (4)	57.9 (11)	22.2 (2)	59.3 (32)	40.0 (2)
Previous caesarean section	22.4 (70)	11.8 (2)	11.6 (15)	55.6 (40)	25.0 (2)	21.1 (4)	2 (22.2)	7.4 (4)	20.0 (1)
Grand multiparity	16.6 (52)	11.8 (2)	12.4 (16)	34.7 (25)	25.0 (2)	21.1 (4)	-	5.6 (3)	-
Diabetes	15.0 (47)	-	18.6 (24)	16.7 (12)	12.5 (1)	10.5 (2)	11.1 (1)	9.3 (5)	40.0 (2)
Anaemia	14.4 (45)	29.4 (5)	6.2 (8)	5.4 (4)	-	26.3 (5)	-	42.6 (23)	-
<b>Other medical disorders</b>	13.1 (41)	11.8 (2)	12.4 (16)	11.1 (8)	12.5 (1)	15.8 (3)	11.1 (1)	14.8 (8)	40.0 (2)
Hypertension	5.8 (18)	-	0.8 (1)	6.9 (5)	12.5 (1)	21.1 (4)	11.1 (1)	11.1 (6)	-
Obesity	3.5 (11)	-	4.7 (6)	1.4 (1)	12.5 (1)	10.5 (2)	-	1.9 (1)	-
Premature rupture of membranes	1.6 (6)	-	2.3 (3)	2.8 (2)	12.5 (1)	-	-	-	-
Prolonged obstructed labour	1.3 (4)	-	-	4.2 (3)	-	5.3 (1)	-	-	-
Preterm labour	1.3 (4)	-	1.6 (2)	1.4 (1)	-	-	-	1.9 (1)	-
Pelvic abnormality	0.6 (2)	-	-	-	-	5.3 (1)	-	1.9 (1)	-
Prolonged pregnancy (≥42 weeks)	0.6 (2)	-	1 (0.8)	1.4 (1)	-	-	-	-	-
Other maternal	3.2 (10)	-	6.2 (8)	2.8 (2)	-	-	-	-	-

Identified contributory conditions	For total MNM events (313) % (n)	For pregnancy with abortive outcome (17) % (n)	For hypertensive disorders of pregnancy (129) % (n)	For obstetric haemorrhage (72) % (n)	For pregnancy-related infection (8) % (n)	For other obstetric complications (19) % (n)	For un-anticipated complications of management (9) % (n)	For non-obstetric complications (54) % (n)	For unspecified causes (5) % (n)
<b>conditions</b>									
<b>Foetal</b>	14.7 (46)	5.9 (1)	17.1 (22)	12 (16.7)	37.5 (3)	21.1 (4)	11.1 (1)	3.7 (2)	20.0 (1)
<b>Multiple gestation</b>	4.2 (13)	5.9 (1)	4.7 (6)	2 (2.8)	12.5 (1)	10.5 (2)	-	1.9 (1)	-
<b>Abnormal presentation of foetus</b>	2.6 (8)	-	1.6 (2)	5.4 (4)	-	5.3 (1)	11.1 (1)	-	-
<b>Oligohydramnios</b>	2.2 (7)	-	3.9 (5)	1.4 (1)	-	5.3 (1)	-	-	-
<b>Foetal abnormality</b>	1.6 (5)	-	0.8 (1)	2.8 (2)	12.5 (1)	-	11.1 (1)	-	-
<b>Polyhydramnios</b>	1.6 (5)	-	1.6 (2)	3 (4.2)	-	-	-	-	-
<b>Others</b>	6.4 (20)	-	9.3 (12)	4 (5.6)	12.5 (1)	5.3 (1)	-	1.9 (1)	20.0 (1)
<b>Interventions</b>	12.8 (40)	17.6 (3)	6.2 (8)	14 (19.4)	37.5 (3)	5.3 (1)	77.8 (7)	5.6 (3)	20.0 (1)
<b>Complications of anaesthesia</b>	2.6 (8)	-	0.8 (1)		-		55.6 (5)	1.9 (1)	20.0 (1)
<b>Failed vacuum extraction/forceps</b>	1.6 (5)	-	0.8 (1)	2.8 (2)	-	5.3 (1)	-	1.9 (1)	-
<b>Failed induction of labour</b>	1.8 (4)	-	-	5.4 (4)	-	-	-	-	-
<b>Failed trial of labour</b>	0.6 (2)	-	-	1.4 (1)	-	-	11.1 (1)	-	-
<b>Other interventions</b>	8.9 (28)	17.6 (3)	5.4 (7)	11.1 (8)	37.5 (3)	5.3 (1)	33.3 (3)	5.6 (3)	-
<b>None identified</b>	31.3 (98)	35.3 (6)	41.9 (54)	12.2 (9)	25.0 (2)	31.6 (6)	11.1 (1)	18.5 (10)	20.0 (1)

### Annex 18: Contributory conditions identified by regional reviewers

Contributory conditions	For the 290 MNM events % (n)	For pregnancy with abortive outcome (11) % (n)	For hypertensive disorders of pregnancy (125) % (n)	For obstetric haemorrhage (74) % (n)	For pregnancy-related infection (7) % (n)	For other obstetric complications (15) % (n)	For un-anticipated complications of management (6) % (n)	For non-obstetric complications (51) % (n)	For MNM with unspecified causes (1) % (n)
	74.5 (216)	54.5 (6)	62.4 (78)	91.9 (68)	85.7 (6)	93.3 (14)	85.3 (5)	78.4 (40)	-
<b>Maternal</b>	68.3 (198)	54.5 (6)	53.6 (67)	89.2 (66)	57.1 (4)	86.7 (13)	50.0 (3)	76.5 (39)	-
<b>Previous caesarean section</b>	22.4 (65)	18.2 (2)	10.4 (13)	48.6 (36)	28.6 (2)	40.0 (6)	16.7 (1)	9.8 (5)	-
<b>Other medical disorders</b>	20.0 (58)	18.2 (2)	17.6 (22)	21.6 (16)	14.3 (1)	33.3 (5)	-	23.5 (12)	-
<b>Diabetes</b>	18.6 (54)	-	21.6 (27)	20.3 (15)	14.3 (1)	20.0 (3)	33.3 (2)	11.8 (6)	-
<b>Anaemia</b>	17.9 (52)	18.2 (2)	10.4 (13)	10.8 (8)	-	33.3 (5)	-	47.1 (24)	-
<b>Grand-multiparity</b>	17.6 (51)	18.2 (2)	8.0 (10)	39.2 (29)	14.3 (1)	40.0 (6)	-	5.9 (3)	-
<b>Hypertension</b>	3.8 (11)	-	2.4 (3)	6.8 (5)	-	6.7 (1)	-	3.9 (2)	-
<b>Obesity</b>	3.8 (11)	-	5.6 (7)	1.4 (1)	14.3 (1)	13.3 (2)	-	-	-
<b>Premature rupture of membranes</b>	2.1 (6)	-	1.6 (2)	2.7 (2)	-	-	-	3.9 (2)	-
<b>Preterm labour</b>	2.1 (6)	-	2.4 (3)	1.4 (1)	-	6.7 (1)	-	2.0 (1)	-
<b>Prolonged obstructed labour</b>	1.0 (3)	-	-	4.1 (3)	-	-	-	-	-
<b>Pelvic abnormality</b>	0.3 (1)	-	-	-	-	-	-	2.0 (1)	-
<b>Other maternal conditions</b>	4.8 (14)	9.1 (1)	9.6 (12)	1.4 (1)	-	-	-	-	-

Contributory conditions	For the 290 MNM events % (n)	For pregnancy with abortive outcome (11) % (n)	For hypertensive disorders of pregnancy (125) % (n)	For obstetric haemorrhage (74) % (n)	For pregnancy-related infection (7) % (n)	For other obstetric complications (15) % (n)	For un-anticipated complications of management (6) % (n)	For non-obstetric complications (51) % (n)	For MNM with unspecified causes (1) % (n)
<b>Foetal</b>	18.6 (54)	9.1 (1)	18.4 (23)	15 (20.3)	42.9 (3)	20.0 (3)	33.3 (2)	13.7 (7)	-
<b>Multiple gestation</b>	4.5 (13)	9.1 (1)	4.8 (6)	1.4 (1)	14.3 (1)	-	-	7.8 (4)	-
<b>Abnormal presentation of foetus</b>	3.8 (11)	-	2.4 (3)	5.4 (4)	-	13.3 (2)	16.7 (1)	2.0 (1)	-
<b>Foetal abnormality</b>	1.7 (5)	-	0.8 (1)	4.1 (3)	14.3 (1)	-	-	-	-
<b>Oligohydramnios</b>	1.7 (5)	-	3.2 (4)	-	-	6.7 (1)	-	-	-
<b>Polyhydramnios</b>	1.4 (4)	-	-	5.4 (4)	-	-	-	-	-
<b>Others</b>	7.9 (23)	-	9.6 (12)	8.1 (6)	14.3 (1)	6.7 (1)	16.7 (1)	3.9 (2)	-
<b>Interventions</b>	9.0 (26)	9.1 (1)	2.4 (3)	16.2 (12)	28.6 (2)	-	66.7 (4)	7.8 (4)	-
<b>Complications of anaesthesia</b>	1.7 (5)	-	-	-	-	-	66.7 (4)	2.0 (1)	-
<b>Failed trial of labour</b>	0.7 (2)	-	-	2.7 (2)	-	-	-	-	-
<b>Failed vacuum extraction/forceps</b>	0.3 (1)	-	-	1.4 (1)	-	-	-	-	-
<b>Failed induction of labour</b>	0.3 (1)	-	0.8 (1)	-	-	-	-	-	-
<b>Other interventions</b>	6.2 (18)	9.1 (1)	1.6 (2)	13.5 (10)	28.6 (2)	-	-	5.9 (3)	-
<b>None identified</b>	25.2 (73)	45.5 (5)	35.6 (47)	8.1 (6)	14.3 (1)	6.7 (1)	16.7 (1)	21.6 (11)	100.0 (1)

### Annex 19: Contributory conditions identified by the national reviewers

Contributory conditions	For the 156 MNM events % (n)	For pregnancy with abortive outcome (4) % (n)	For hypertensive disorders of pregnancy (65) % (n)	For obstetric haemorrhage (43) % (n)	For pregnancy-related infection (2) % (n)	For other obstetric complications (7) % (n)	For unanticipated complications of management (6) % (n)	For non-obstetric complications (29) % (n)
	82.1 (128)	75.0 (3)	75.4 (49)	97.7 (42)	100.0 (2)	100.0 (7)	66.7 (4)	72.4 (21)
<b>Maternal</b>	78.8 (123)	75.0 (3)	70.8 (46)	93.0 (40)	100.0 (2)	100.0 (7)	66.7 (4)	72.4 (21)
Previous caesarean section	26.3 (41)	25.0 (1)	13.8 (9)	53.5 (23)	50.0 (1)	42.9 (3)	16.7 (1)	10.3 (3)
Diabetes	23.7 (37)	-	24.6 (16)	32.6 (14)	50.0 (1)	28.6 (2)	33.3 (2)	6.9 (2)
Grand-multiparity	21 (34)	-	16.9 (11)	44.2 (19)	-	28.6 (2)	-	6.9 (2)
Anaemia	21.2 (33)	25.0 (1)	12.3 (8)	16.3 (7)	-	14.3 (1)	16.7 (1)	51.7 (15)
Other medical disorders	20.2 (32)	50.0 (2)	12.3 (8)	23.3 (10)	-	28.6 (2)	50.0 (3)	24.1 (7)
Obesity	7.7 (12)	-	10.8 (7)	4.7 (2)	-	42.9 (3)	-	-
Hypertension	6.5 (10)	-	4.6 (3)	9.3 (4)	-	14.3 (1)	16.7 (1)	3.4 (1)
Preterm labour	2.6 (4)	-	1.5 (1)	2.3 (1)	-	-	-	6.9 (2)
Pelvic abnormality	1.9 (3)	-	-	7.0 (3)	-	-	-	-
Premature rupture of membranes	1.9 (3)	-	1.5 (1)	-	-	14.3 (1)	-	3.4 (1)
Prolonged obstructed labour	1.3 (2)	-	-	4.7 (2)	-	-	-	-
Other maternal conditions	14.1 (22)	25.0 (1)	29.2 (19)	4.7 (2)	-	-	-	-
Prolonged pregnancy (42 weeks)	-	-	-	-	-	-	-	-
<b>Foetal</b>	18.6 (29)	-	21.5 (14)	25.6 (11)	50.0 (1)	-	-	10.3 (3)
Multiple gestation	4.5 (7)	-	6.2 (4)	4.7 (2)	-	-	-	3.4 (1)
Abnormal presentation of foetus	2.6 (4)	-	1.5 (1)	4.7 (2)	-	-	-	3.4 (1)
Polyhydramnios	2.6 (4)	-	-	7.0 (3)	-	-	-	3.4 (1)
Foetal abnormality	1.9 (3)	-	1.5 (1)	2.3 (1)	50.0 (1)	-	-	-

Contributory conditions	For the 156 MNM events % (n)	For pregnancy with abortive outcome (4) % (n)	For hypertensive disorders of pregnancy (65) % (n)	For obstetric haemorrhage (43) % (n)	For pregnancy-related infection (2) % (n)	For other obstetric complications (7) % (n)	For unanticipated complications of management (6) % (n)	For non-obstetric complications (29) % (n)
Oligohydramnios	1.9 (3)	-	4.6 (3)	-	-	-	-	-
Others	7.7 (12)	-	10.8 (7)	9.3 (4)	-	-	-	3.4 (1)
Interventions	16.0 (25)	25.0 (1)	9.5 (6)	20.9 (9)	50.0 (1)	28.6 (2)	33.3 (2)	4 (13.8)
Failed trail of labour	2.6 (4)	-	1.5 (1)	2.3 (1)	-	-	16.7 (1)	3.4 (1)
Complications of anaesthesia	1.9 (3)	-	-	-	-	14.3 (1)	16.7 (1)	3.4 (1)
Failed vacuum extraction/forceps	0.6 (1)	-	-	2.3 (1)	-	-	-	-
Failed induction of labour	0.6 (1)	-	1.5 (1)	-	-	-	-	-
Other interventions	10.9 (17)	25.0 (1)	6.4 (4)	16.3 (7)	50.0 (1)	28.6 (2)	-	6.9 (2)
None identified	17.9 (28)	25.0 (1)	24.6 (16)	2.3 (1)	-	-	33.3 (2)	27.6 (8)

## Annex 20: Contributory conditions identified by the International Expert Panel

Contributory conditions	For 156 MNM events % (n)	For pregnancy with abortive outcome (4)	For hypertensive disorders of pregnancy (65) % (n)	For obstetric haemorrhage (40) % (n)	For pregnancy-related infection (1) % (n)	For other obstetric complications (13) % (n)	For unanticipated complications of management (5) % (n)	For non-obstetric complications (28) % (n)
<b>MNM with identified contributory conditions n (%)</b>	61.5 (96)	-	50.8 (33)	77.5 (31)	100.0 (1)	84.6 (11)	100.0 (5)	28.6 (15)
<b>Maternal</b>	53.8 (84)	-	43.1 (28)	67.5 (27)	100.0 (1)	76.9 (10)	80.0 (4)	50 (14)
<b>Previous caesarean section</b>	16.7 (26)	-	6.2 (4)	37.5 (15)	-		40.0 (2)	-
<b>Anaemia</b>	16.7 (26)	-	10.8 (7)	17.5 (7)	-	15.4 (2)	20.0 (1)	32.1 (9)
<b>Diabetes</b>	14.7 (23)	-	21.5 (14)	10.0 (4)	-	23.1 (3)	-	7.1 (2)
<b>Other medical disorders</b>	12.8 (20)	-	9.2 (6)	15.0 (6)	100.0 (1)	7.7 (1)	60.0 (3)	10.7 (3)
<b>Grand multiparity</b>	11.5 (18)	-	6.2 (4)	30.0 (12)	-	7.7 (1)	20.0 (1)	-
<b>Obesity</b>	8.3 (13)	-	7.7 (5)	7.5 (3)	-	38.5 (5)	-	3.6 (1)
<b>Hypertension</b>	2.6 (4)	-	4.1 (2)	-	-	7.7 (1)	-	3.6 (1)
<b>Preterm labour</b>	2.6 (4)	-	4.6 (3)	-	-	7.7 (1)		-
<b>Premature rupture of membranes</b>	0.6 (1)	-	1.5 (1)	-	-	-	-	-
<b>Prolonged obstructed labour</b>	0.6 (1)	-	-	2.5 (1)	-	-	-	-
<b>Other maternal conditions</b>	0.6 (1)	-		-	-	-	-	-
<b>Prolonged pregnancy (42 weeks)</b>	-	-	-	-	-	-	-	-
<b>Pelvic abnormality</b>	-	-	-	-	-		-	-
<b>Foetal</b>	12.2 (19)	-	12.3 (8)	17.5 (7)	-	7.7 (1)	20.0 (1)	7.1 (2)
<b>Multiple gestation</b>	3.2 (5)	-	3 (4.6)	2.5 (1)	-	7.7 (1)	-	-
<b>Polyhydramnios</b>	1.9 (3)	-	1.5 (1)	5.0 (2)	-	-	-	-
<b>Abnormal presentation of foetus</b>	0.6 (1)	-	1.5 (1))	-	-	-	-	-
<b>Foetal abnormality</b>	0.6 (1)	-	-	2.5 (1)	-	-	-	-

Contributory conditions	For 156 MNM events % (n)	For pregnancy with abortive outcome (4)	For hypertensive disorders of pregnancy (65) % (n)	For obstetric haemorrhage (40) % (n)	For pregnancy-related infection (1) % (n)	For other obstetric complications (13) % (n)	For unanticipated complications of management (5) % (n)	For non-obstetric complications (28) % (n)
Oligohydramnios	-	-	-	-	-	-	-	-
Others	7.1 (11)	-	6.2 (4)	10.0 (4)	-	-	20.0 (1)	7.1 (2)
Interventions	15.4 (24)	-	9.2 (6)	27.5 (11)	-	15.4 (2)	80.0 (4)	3.6 (1)
Complications of anaesthesia	2.6 (4)	-	-	-	-	-	60.0 (3)	3.6 (1)
Failed trial of labour	1.3 (2)	-	-	5.0 (2)	-	-	-	-
Failed vacuum extraction/forceps	-	-	-	-	-	-	-	-
Failed induction of labour	1.3 (2)	-	1.5 (1)	-	-	7.7 (1)	-	-
Other interventions	10.9 (17)	-	7.7 (5)	22.5 (9)	-	7.7 (1)	40.0 (2)	-
None identified	38.5 (60)	100.0 (4)	49.2 (32)	22.5 (9)	-	-	-	46.4 (13)

## Annex 21: National and International Panels Assessment Differences in MNM Events

The following lists MNM events with a difference in the assessment of the quality of care between the national reviewers and the international expert panel

1. MNM events where expert panel identified areas for improvement in care, which might have made a difference to the outcome while the national reviewers found that the overall care was good.

Underlying causes of the MNM events	No. MNM events
<b>Hypertensive disorders of pregnancy</b>	7/65
Severe pre-eclampsia	2
Eclampsia	3
HELLP syndrome	2
<b>Obstetric haemorrhage</b>	4/40
Intraoperative surgical haemorrhage	3
Traumatic and uterine atony	1
<b>Other obstetric complications</b>	2/13
Wernicke encephalopathy	1
Peripartum cardiomyopathy	1
<b>Un-anticipated complications of management</b>	3/5
Complications of anaesthesia	2
Cardiac arrest during CS under spinal anaesthesia with midazolam sedation	1
<b>Non-obstetric complications</b>	4/28
Sickle cell disease	2
Epilepsy	1
Bleeding from left adnexa	1

2. MNM events where the expert panel found the overall there was good care while the national reviewers identified areas for improvement in care, which might have made a difference to the outcome.

<b>Underlying causes of the MNM events</b>	<b>No. MNM events</b>
Pregnancy with abortive outcome (ruptured ectopic pregnancy)	1/4
Hypertensive disorders of pregnancy	10/65
Severe pre-eclampsia	5
HELLP syndrome	2
Eclampsia	3
Obstetric haemorrhage	2/40
Abruptio placenta	1
Uterine rupture	1
Non-obstetric complications (e.g. sickle cell disease)	2/29

## Annex 22: Most common factors identified by hospital reviewers per ICD- group of underlying causes of MNM

ICD-group of underlying causes (n= no of MNM events)	Factors related to organisation of care (% n)	Factors related to health care team (% n)	Factors related to woman (% n)
<b>Pregnancy with abortive outcome (n=17)</b>	Factors related to staff (23.5%, n=4)	Delay in emergency response (100%, n=17)	Delay in seeking care (11.8%, n=2)
	Factors related to equipment (17.6%, n=3)	Delay in diagnosis (93.8%, n=15)	-
	Non-availability of blood (17.6%, n=3)	Management failure (82.4%, n=14)	-
<b>Hypertensive disorders of pregnancy (n=129)</b>	Factors related to staff (6.2%, n=8) Inadequate number of staff (2.3%, n=3) Poor access to senior staff (3.1%, n= 4)	Delay in emergency response (93.8%, n=121)	Non-adherent to treatment (10.9% n=14)
	Non-availability of blood (3.1%, n=4)	Failure in monitoring (93.8%, n=121)	Decline medication or procedure (2.3%, n=3)
	Factors related to guidelines (2.3%, n=3) Non-availability (1.6% n=2), outdated (0.8 n=1)	Failure in management (90.7%, 117)	Late booking for ANC care (2.3%, n=3)
	Non-availability of medication (1.6%, n=2)	Delay in diagnosis (78.7%, n=100)	-
<b>Obstetric haemorrhage (n=75)</b>	Factors related to staff (18.1%, n=13) Inadequate number of staff (9.7%, n=7) Poor access to senior staff (9.7%, n=7)	Delay in diagnosis of the condition (11.1%, n= 8)	Delay in seeking care (5.6%, n=4)
	Non-availability of equipment (9.7%, n=7)	Inappropriate management (9.7%, n=7)	Decline medication or procedure (4.2%, n=3)
	Related to guidelines (8.3%, n=6) Non-availability of blood/blood products (8.3%, n=6)	Delay in referral to a higher care facility (6.9%, n= 5)	Non-adherent to treatment (2.8%, n=2)

ICD-group of underlying causes (n= no of MNM events)	Factors related to organisation of care (% n)	Factors related to health care team (% n)	Factors related to woman (% n)
<b>Pregnancy related infection (n=8)</b>	Factors related to staff (12.5%, n=1)	Incomplete or delay in assessment of condition (87.5%, n=7)	Non-adherent to treatment (12.1%, n=1)
	-	Inappropriate management (25.0%, n=2)	-
	-	Delay in diagnosis (25.0%, n= 2)	-
<b>Other obstetric complications</b>	Outdated guidelines (5.0%, n=1)	Inappropriate management (15.8%, n=3)	No ANC care (5.3%, n= 1)
	-	Delay in assessment (5.3%, n=1)	
	-	Failure in monitoring the condition	
<b>Un-anticipated complications of management (n=1)</b>	Non-availability of equipment (11.1%, n=1)	In-appropriate management (11.1%, n=1)	-
	Non-availability of guidelines (11.1%, n=1)	-	
<b>Non-obstetric complications</b>	Factors related to staff (11.1%, n= 6) Inadequate number of staff (8.9 %, n=5)	Failure in monitoring (98.1%, n= 53)	Non-adherent to treatment (14.8%, n= 8)
	Factors related to guidelines (3.7%, n= 2)	Failure in recognition of severe condition (92.6%, n= 50)	Decline medication (3.7%, n=2)
	Factors related to medications (3.7%, n= 2)	Delay in emergency response (94.4%, n= 51)	Delay in seeking care (3.7%, n= 2)

### Annex 23: Most common factors identified by regional reviewers per ICD-group of underlying causes of MNM

ICD-group of underlying causes (n= no of MNM events)	Factors related to organisation of care (% , n)	Factors related to health care team (% , n)	Factors related to woman (% , n)
<b>Pregnancy with abortive outcome (n=11)</b>	Outdated guidelines (9.1%, n=1)	Failure to recognise the seriousness of the condition (9.1%, n= 1)	No ANC care (27.3%, n=3)
	-	Delay in diagnosis of the condition (9.1%, n= 1)	Delay seeking care (9.1%, n=1)
	-	Inappropriate management (9.1%, n= 1)	Late booking (9.1%, n=1)
<b>Hypertensive disorders of pregnancy (n=125)</b>	Factors related to policy and guidelines (6.4%, n= 8) Non-availability of guidelines (3.2 % n=4) Non-availability of policy (2.4%, n=3)	Failure to recognise the seriousness of the condition (12.0%, n=15)	Non-adherent to treatment (13.7%, n=17)
	Factors related to staff (3.2%, n=4) Inadequate number 1.6 (n=2) Poor access to senior staff 1.6	Inappropriate management (9.6%, n= 12)	Delay seeking care (13.7%, n=17)
	Non-availability of medication (2.4%, n=3) Transportation problem (referral system) (2.4%, n= 3)	Delay in referral to higher care facility (6.4%, n= 8)	Late booking (8.8%, n=11)
<b>Obstetric haemorrhage (n=74)</b>	Factors related to staff (13.5%, n=10) Inadequate number of staff (8.1%, n=6) Poor access to senior staff (5.4%, n=4)	Failure to recognise the seriousness of the condition (9.5%, n=7)	Delay seeking care (12.2%, n=9)
	Non-availability of equipment (9.5%, 7)	Delay in diagnosis of the condition (8.1%, n= 6)	Non-adherent to treatment (4.1%, n= 3)
	Non-availability of blood/blood products (5.4%, n=4)	Delay in referral to higher care facility (6.8%, n= 5)	Declined medication or procedure (2.7%, n=2)
<b>Pregnancy related infection (n=7)</b>	-	Failure to recognise the seriousness of the condition(14.3%, n=1)	Declined medication or procedure (14.3%, n=1)
		Inappropriate management (14.3%, n= 1)	-
		Failure to assess the severity of the condition (14.3%, n= 1)	-

ICD-group of underlying causes (n= no of MNM events)	Factors related to organisation of care (% , n)	Factors related to health care team (% , n)	Factors related to woman (% , n)
<b>Other obstetric complications (n=15)</b>	Poor access to senior staff (6.7%, n=1)	Delay in diagnosis of the condition (20.0%, n= 3)	Delay seeking care (6.7%, n=1)
	Non-availability of equipment (6.7%, n=1)	Failure to recognise the seriousness of the condition (13.3%, n=2)	Non-adherent to treatment (6.7%, n=1)
	Non-availability of blood (6.7%, n=1)	Inappropriate management (13.3%, n= 2) Delay in referral to higher care facility (13.3%, n=2)	
<b>Un-anticipated complications of management (n=6)</b>	Non-availability of medication (16.7%, n=1)	-	-
	Non-availability of laboratory test (16.7%, n=1)	-	-
<b>Non-obstetric complications (n=51)</b>	Non-availability of blood (5.9%, n=3)	Failure to recognise the seriousness of the condition (11.8%, n=6)	Delay in seeking care (13.7%, n=7)
	Non-availability of equipment (2.0%, n=1) Delay access to laboratory test result (2.0%, n=1)	Delay in diagnosis of the condition (7.8%, n=4)	Non-adherent to treatment (11.8%, n=6)
	Long distance from healthcare facility (2.0%, n=1)	Failure to assess the severity of the condition (3.9%, n=2)	Declined medications or procedure (9.8%, n=5)

## Annex 24: Most common factors identified by the national reviewers per ICD-group of underlying causes of MNM

ICD-group of underlying causes (n= no of MNM events)	Factors related to organisation of care (% , n)	Factors related to health care team (% , n)	Factors related to woman (% , n)
<b>Pregnancy with abortive outcome (n=4)</b>	Related to staff (25.0%, n=1)	Communication failure (25.0%, n=1)	No ANC care (75.0%, n=3)
	Long distance from healthcare facility (25.0%, n=1)	-	Delay seeking care (25.0%, n=1)
	Non-availability equipment (25.0%, n=1)	-	-
<b>Hypertensive disorders of pregnancy (n=65)</b>	Factors related to policy and guidelines (7.7%, n= 5) Non-availability of guidelines (3.1% n=2) Outdated guidelines (3.1%, n=1) Non-availability of policy (1.5%,1)	Failure to recognise the seriousness of the condition (33.8%, n=22)	Non-adherent to treatment (15.4%, n=10)
	Factors related to staff (4.6%, n=3) Inadequate number (3.1%, n=2) Poor access to senior staff (1.5%, n=1)	Inappropriate management (27.7%, n=18)	Late booking (13.8%, n=9)
	Related to referral (3.1%, n=2) (Transportation problem (1.5%, n=1) Non-availability of bed in higher care facility (1.5%, n=1)	Failure to assess severity of the condition (12.8%, n=8)	Delay seeking care (10.8%, n=7)
	Factors related to staff (11.6%, n=5) Inadequate number of staff (9.3%, n=4) Poor access to senior staff (2.3%, n=1)	Failure to recognise the seriousness of the condition (20.9%, n=9)	Delay seeking care (7%, n=3)
	Factors related to policy and guidelines (11.6%, n=5) Non-availability of guidelines (4.7%, n=2) Non-availability of policy (4.7%, n=2)	Failure to assess severity of the condition (14.0%, n=6)	Non-adherent to treatment (4.7%, n=2)
	Factors related to referral (9.3%, n=4) Transportation problem (4.7%, n=2) Non-availability of bed in higher care facility (4.7%, n=2)	Delay in diagnosis of the condition (11.6%, n=5) Inappropriate management (11.6%, n=5)	Declined medication or procedure (2.3%, n=1)
<b>Obstetric haemorrhage (n=43)</b>			

ICD-group of underlying causes (n= no of MNM events)	Factors related to organisation of care (% , n)	Factors related to health care team (% , n)	Factors related to woman (% , n)
<b>Pregnancy related infection (n=2)</b>	-	-	-
<b>Other obstetric complications (n=7)</b>	Related to staff (28.6%, n=2) Poor access to senior staff (28.6%, n=2) Inadequate number (14.4%, n=1)	Failure to recognise the seriousness of the condition (28.6%, n=2)	Delay seeking care (6.7 %, n=1)
	Non-availability of bed in higher care facility (14.3, n=1)	Delay in diagnosis of the condition (14.3%, n=1)	Non-adherent to treatment (6.7%, n=1)
	Inaccurate test result (14.3%, n=1)	Delay in referral to higher care facility (14.3%, n=1) Communication failure (14.3%, n=1)	
<b>Un-anticipated complications of management (n=6)</b>	Non-availability of medication (16.7%, n=1)	-	-
	Non-availability of laboratory test (16.7%, n=1)	-	-
<b>Non-obstetric complications (n=29)</b>	Related to policy and guidelines (17.2%, n=5) Non-availability of policy (6.9%, n=2) Outdated guidelines (4.7%, n=2)	Failure to recognise the seriousness of the condition (24.1%, n=7)	Non-adherent to treatment (17.5%, n=5)
	Non-availability of equipment (3.4%, n=1) Non-availability of bed in higher care facility (3.4%, n=1)	Incomplete or delay in assessment of the condition (17.2, n=5)	Declined medications or procedure (13.8, n=4)
	Non-availability of blood (3.4%, n=1)	Failure to assess the severity of the condition (13.8%, n=4) Delay in referral to higher care facility (13.8%, n=4) Failure to involve other specialities (13.8%, n=4)	No ANC care (10.3%, n=3)

**Annex 25: Most common factors identified by the international expert reviewers per ICD-group of underlying causes of MNM**

ICD-group of underlying causes (n= no of MNM events)	Factors related to organisation of care (%, n)	Factors related to health care team (%, n)	Factors related to woman (%, n)
<b>Pregnancy with abortive outcome (n=4)</b>	-	Incomplete or delayed in diagnosis (25.0%, n=1)	No ANC care (25.0%, n=1)
	-	Failure to recognise the seriousness of the condition (25.0%, n=1)	Delay seeking care(25.0%, n=1)
	-	Inappropriate management (25.0%, n=1)	-
<b>Hypertensive disorders of pregnancy (n=65)</b>	Factors related to policy and guidelines (24.6%, n=16) Non-availability of policy (20%, n=13) Outdated guidelines (18.5%, n=12) Non-availability of policy (4.3%, n=6)	Failure to recognise the seriousness of the condition (25.0%, n=1)	Non-adherent to treatment (13.8%, n=9)
	Factors related to medication (12.3%, n=8)	Inappropriate management (32.2%, n=21)	Declined medication or procedure (9.2%, n=6)
<b>Obstetric haemorrhage (n=40)</b>	Factors related to referral (12.5%, 5) Transportation problem (5.0%, n=2) Non-availability of bed in higher care facility (5.0%, n=2)	Inappropriate management (22.1%, n=9)	Declined medication or procedure (7.5%, n=3)
	Factors related to policy and guidelines (7.5%, n=3) Outdated guidelines (5.0%, n=2) Non-availability of guidelines (2.5%, n=1) Non-availability of policy (2.5%, n=1)	Failure to recognise the seriousness of the condition (15.0%, n=6)	Non-adherent to treatment (5.0%, n=2)
	Non-availability of equipment (5.0%, n=2) Non-availability of medication (5.0%, n=2) Non-availability of laboratory test (5.0%, n=2) Long distance from healthcare facility (5.0, n=2)	Delay in emergency response (12.5%, n=5)	Delay seeking care (2.5%, n=1)

ICD-group of underlying causes (n= no of MNM events)	Factors related to organisation of care (%, n)	Factors related to health care team (%, n)	Factors related to woman (%, n)
<b>Pregnancy related infection (n=1)</b>	-	-	-
<b>Other obstetric complications (n=13)</b>	Related to policy and guidelines (30.8%, n=4) Non-availability of guidelines (15.4%, n=2) Outdated guidelines (7.7%, n=1) Non-availability of policy (7.7%, n=1)	Inappropriate management (38.5%, n=5)	Declined medication or procedure (15.4%, n=2)
	Non-availability of medication (7.7%, n=1)	Delay in diagnosis of the condition (30.8%, n=4)	Delay in seeking care (7.7%, n=1)
	-	Failure to recognise the seriousness of the condition (15.4%, n=2) Failure to assess the severity of the condition (15.4%, n=2) Delay in emergency response (15.4%, n=2)	No ANC care (7.7%, n=1)
<b>Un-anticipated complications of management (n=5)</b>	Related to policy and guidelines (20.0%, n=1)	Incomplete or delayed assessment of condition (40.0%, n=2)	-
	Related to blood (20.0%, n=1)	Failure to recognise the seriousness of the condition (20.0%, n=1) Failure to assess severity of the condition (20.0%, n=1)	-
	-	Inappropriate management (20.0%, n=1)	-
<b>Non-obstetric complications (n=28)</b>	Related to referral (7.1%, n=2) Transportation problem (3.6%, n=1) Non-availability of bed in higher care facility (3.6%, n=1)	Inappropriate management (21.4%, n=6)	Non-adherent to treatment (14.3%, n=4)
	Related to referral (7.1%, n=2) Transportation problem (3.6%, n=1) Non-availability of bed in higher care facility (3.6%, n=1)	Inappropriate management (21.4%, n=6)	Non-adherent to treatment (14.3%, n=4)
	Related to referral (7.1%, n=2) Transportation problem (3.6%, n=1)	Inappropriate management (21.4%, n=6)	Non-adherent to treatment (14.3%, n=4)

ICD-group of underlying causes (n= no of MNM events)	Factors related to organisation of care (%, n)	Factors related to health care team (%, n)	Factors related to woman (%, n)
	Non-availability of bed in higher care facility (3.6%, n=1)		

## Annex: 26: Comparison of lessons to be learned identified by different groups of reviewers

Lessons identified by hospital reviewers	% (n) of MNM with identified lesson	Lesson identified by regional reviewers	% (n) of MNM with identified lesson	Lessons identified by national reviewers	% (n) of MNM with identified lesson	Lessons identified by international reviewers	% (n) of MNM with identified lesson
<b>For healthcare system</b>							
Having clear referral guidelines and protocols is necessary for obstetric emergency	3.2 (5)	There is a need to increase public and women awareness about the importance of early booking and follow-up with antenatal care clinic, as well as warning signs during pregnancy.	9.0 (14)	Update the current National Antenatal, Childbirth and Postpartum Care guidelines in particular management severe pre-eclampsia. Expand the guidelines to include management of peripartum cardiomyopathy, SCD in pregnancy, abnormal placentation, and Caesarean scar pregnancy	6.4 (10)	Review/introducing guidelines for the management of pre-eclampsia/eclampsia (including fluid management), invasive placentation, PPH, thromboprophylaxis, hyperemesis gravidarum,	29.5 (46)
Increase public, family and women awareness about early ANC booking and importance of ANC follow-up and complications arising in pregnancy	2.6 (4)	There is an urgent need to conduct obstetric emergency drills on obstetric emergency and training healthcare providers in early recognition and management of severe obstetric complications. Head of obstetrics and gynaecology should coordinate with the Department of Woman and Child and other related departments to	7.7 (12)	An urgent need to conduct obstetric emergency drills. Train healthcare providers at all levels of public healthcare and private healthcare facilities on recognition and management of severe complication in particular eclampsia.	6.4 (10)	Multidisciplinary team training (including anaesthetists) and competence assessment in obstetric emergencies in particular severe pre-eclampsia/eclampsia with the provision of an emergency trolley containing algorithms and drugs. There should be training in situational awareness and surgical techniques to reduce	16.7 (26)

Lessons identified by hospital reviewers	% (n) of MNM with identified lesson	Lesson identified by regional reviewers	% (n) of MNM with identified lesson	Lessons identified by national reviewers	% (n) of MNM with identified lesson	Lessons identified by international reviewers	% (n) of MNM with identified lesson
		organise such training.				obstetric haemorrhage.	
An urgent need to conduct obstetric emergency drills and training healthcare providers on recognition and management of severe complication such as severe pre-eclampsia, severe obstetric haemorrhage, etc.	2.6(4)	There is a need to review and update the current guidelines for primary healthcare level on the management of the hypertensive disorder in pregnancy, especially management of eclampsia. There is a need to expand the guidelines for secondary care level on antenatal care to include management of asthma during pregnancy, and invasive placenta.	2.6 (4)	Increase public, families and women awareness about the importance of early ANC booking, ANC follow-up and complications arising during pregnancy	5.8 (9)	Audit cases with severe maternal complications, disseminate experiences, success stories and lessons learnt locally.	1.3 (2)
There is a need to have updated guidelines for the management of common obstetric complication in particular for severe pre-eclampsia/ eclampsia, abnormal placentation, SCD, peripartum cardiomyopathy	1.9 (3)	Reviewing the number of staff in maternity units and ensuring the availability of adequate numbers of staff in particular senior-level staff at all levels of healthcare facilities. There is a need to ensure the availability of adequate number obstetric consultants in all maternity units and increase the number of midwives to deliver one to one care	1.9 (3)	Ensure availability and sustainable supply of life-saving medication and equipment in particular magnesium sulphate at primary healthcare level private healthcare facilities, Bakriballoon and cell saver in regional hospitals	2.6 (4)	Ensure the availability of life-saving medication in particular magnesium sulphate in all healthcare facilities.	1.3 (2)

Lessons identified by hospital reviewers	% (n) of MNM with identified lesson	Lesson identified by regional reviewers	% (n) of MNM with identified lesson	Lessons identified by national reviewers	% (n) of MNM with identified lesson	Lessons identified by international reviewers	% (n) of MNM with identified lesson
Ensure availability of adequate numbers of staff (obstetrician, midwives and nurses) in particular senior-level staff at all levels of healthcare facilities	1.9 (3)	Ensure availability and sustainable supply of life-saving medication and equipment in particular magnesium sulphate at primary healthcare level and Bakriballoon, blood exchange machine at regional hospitals. Local mechanism with focal person needs to be established to monitor the supply of these essential medications and equipment at each healthcare facility.	0.6 (1)	There should be clear referral guidelines and protocols for obstetric emergency	1.9 (3)	There should be clear referral guidelines and protocols for high-risk pregnancies and obstetric complications.	0.6 (1)
<b>For clinical management</b>							
Early involvement of a multidisciplinary team in the management of a woman with medical disorders and those with obstetric complication is necessary to improve the outcome of mother and newborn	12.2 (19)	Identify women with high-risk pregnancy for early referral to secondary or tertiary care level based on risk factors. For early pregnancy, there should be a plan for antenatal care and delivery for these pregnancies	7.1 (11)	Healthcare provider should follow the national guidelines for the management of hypertensive disorders of pregnancy to prevent maternal morbidity and mortality.	10.3 (16)	Timelines of events, vital signs, estimated blood loss, drugs, fluid balance should be recorded clearly to highlight the requirement for action. Use tool similar to the Modified Early Warning System so that vital measurements can be charted on a timeline and comparisons, interpretation and action taken accordingly.	12.8 (20)

Lessons identified by hospital reviewers	% (n) of MNM with identified lesson	Lesson identified by regional reviewers	% (n) of MNM with identified lesson	Lessons identified by national reviewers	% (n) of MNM with identified lesson	Lessons identified by international reviewers	% (n) of MNM with identified lesson
Measure and record of BP correctly and urinalysis at each antenatal visit, intrapartum and postpartum. Woman with hypertensive disorders needs regular check-up and monitoring. They need to be referred early from lower levels of healthcare to an obstetric-led unit. Healthcare providers need to be alert for signs of deterioration and eclampsia.	10.9 (17)	Improve documentation of care given and events in the maternal Health Record and the patient medical record. Vital signs, the sequence of events and monitoring instruction should be recorded clearly	7.1 (11)	Senior healthcare providers need to be involved early in deciding management of obstetric complication to avoid deterioration. A senior obstetrician should be available 24 hours in all maternity units.	9.6 (15)	Improved assessment of patients with hypertensive disorders of pregnancy for early recognition of symptoms of pre-eclampsia. A clear plan of management, including investigations and treatment, should be started in all levels of care.	6.4 (10)
To provide health education and counselling for women with high-risk pregnancy such as SCD, pre-eclampsia on recognition of warning signs to avoid delay in seeking care. Involvement of family member/s should be encouraged in health education and counselling.	8.3 (13)	A multidisciplinary team in the management of a woman with medical conditions and severe complications	7.7 (11)	Healthcare providers should use monitoring systems such as partogram and obstetric early warning system to monitor vital signs and record interventions. The sequence of events, interventions and operation findings should be recorded clearly in the patient medical record.	8.3 (13)	In the patient with severe pre-eclampsia, review fluid management and use of fluid balance chart. Healthcare providers should be more rigour in fluid restriction in cases of severe pre-eclampsia, avoiding fluid boluses and frusemide for oliguria.	6.4 (10)
Early involvement of senior doctors (consultant) in the management of high-risk pregnancy and women with complication improve the	5.8 (9)	Provide counselling and health education for a grand multiparous woman on family planning and the increased risk of obstetric bleeding with	6.4 (10)	There should be early involvement of a multidisciplinary team in the care of high-risk pregnancies, in particular, those with medical	8.3 (13)	There should be a multidisciplinary team managing complex patients. One senior doctor should be responsible for leading and coordinating the care	5.8 (9)

Lessons identified by hospital reviewers	% (n) of MNM with identified lesson	Lesson identified by regional reviewers	% (n) of MNM with identified lesson	Lessons identified by national reviewers	% (n) of MNM with identified lesson	Lessons identified by international reviewers	% (n) of MNM with identified lesson
outcome. For these women, a plan of care/management from the time of first ANC visit should be discussed with a senior doctor		frequent pregnancies.		disorders such as SCD and cardiac diseases. The multidisciplinary team approach is also necessary for the management of obstetric emergencies to improve the outcome.		provided by the team.	
Anticipate haemorrhage and arrange an adequate number of blood products for patients with a previous uterine scar. There is a high risk of bleeding in emergency c-section in the second stage of labour	4.5 (7)	A senior obstetrician should be involved early in complicated surgery, management of high-risk pregnancy and patient with severe complication	5.1 (8)	Counselling women with a high-risk pregnancy should be counselled about their condition, warning signs during pregnancy, management plan. Counselling should during postpartum period should include family planning and plan for future pregnancy.	7.7 (12)	Improve risk assessment at booking visit for ANC. There should be a clear care plan for a woman on the first hospital appointment, including mode of delivery.	5.1 (8)

## Annex 27: Summary of action plan to improve quality of maternity services in Oman based on study findings

Area	Action to be taken	Responsible department/person	Time frame
Organisation of care			
1. Staff	Encourage Omani staff to join midwifery and obstetric speciality training programmes Recruitment of additional number of obstetricians Improve financial and nonfinancial incentives for midwives and obstetricians Have in-house on-call senior specialist for obstetric department in hospitals providing maternity care Create a national recertification program for old staff every year	MoH (recruitment and training department) Private institutions and other non-MoH healthcare facilities, OMSB <sup>1</sup>	2 years
2. Medication	National and local monitoring for continuous supply and redistribution of medications, in particular lifesaving medication  Provide alternative medications for non-available one that would have similar action	MoH-HQ  Nurse in-charge and pharmacist in the health institutions  Medical pharmacy	6 months  3 months
3. Blood and blood products	Blood donation campaigns nationally and at community level MoH to create blood bank facility for healthcare facility with maternity unit  Create protocol for urgent respond for emergency call for blood	MoH	Immediately

<sup>1</sup> OMSB: Oman Medical Speciality Board

Area	Action to be taken	Responsible department/person	Time frame
4. Equipment	<p>MoH to provide all secondary and tertiary settings with adequate numbers of CTG machines, Echo, CT Angio and other necessary equipment</p> <p>Routine checks of equipment Create checklists for the equipment Create an emergency repair team</p>	Hospitals, MoH and community	Equipment to be provided when needed, ideally within 3 months
5. Laboratory service	Accreditation of all laboratory facilities		Within 1 year
6. Guidelines	<p>Update the guidelines every 3 years In-cooperate knowledge about the updated guidelines in staff appraisal</p> <p>Distribute copy of the updated guidelines of different levels to all health institution including the privates</p>	Woman and Child Health (WCH) Department (MoH) in collaboration with OSOG <sup>1</sup> , OMSB, staff development departments in each hospital	Immediate and on regular basis every 3 years
7. Transportation	<p>Create clear protocols for referrals including mode of transport, escort system, and first line management</p> <p>Provide adequate number of ambulance to all health institutions based on the need and service provided Include availability of ambulance in criteria of illegibility of private institutions providing maternity care</p> <p>Provide easy access to ambulance and helicopter</p>	<p>Woman and Child Health Department</p> <p>Administration services in MoH</p> <p>Directorate General of Private Institutions</p> <p>MoH with Armed Forces and Royal Oman Police</p>	<p>1 year</p> <p>3 years</p> <p>Within 1 year</p> <p>Within 1 year</p>

<sup>1</sup> OSOG: Omani society of obstetrics and gynaecology



Area	Action to be taken	Responsible department/person	Time frame
Healthcare team			
1. Recognise the seriousness of woman's condition	<p>Incorporate and activate electronic monitoring system like partogram and Maternal Early Obstetrics Warning system (MEOWS)</p> <p>Audit the use of these monitoring systems and the implementation of guidelines</p> <p>Conduct training workshops in obstetric emergency at national and regional level</p> <p>Conduct obstetric emergency drills</p> <p>Continuous auditing these training</p>	<p>Women and Child Health Department with ICT department Private health institutions</p> <p>Training department in secondary and tertiary hospitals OSOG</p> <p>Department of Quality Assurance</p>	<p>Immediate action</p> <p>One year</p> <p>Twice yearly</p>
2. Inappropriate management	<p>Conducting training sessions related to common obstetrics conditions</p> <p>Mandate the staff to attend CME<sup>1</sup> activities on regular basis under the supervision of the authorise to enhance their knowledge &amp; skills</p> <p>Audit adherence to guidelines and protocol</p> <p>Activate rapid response team in secondary and tertiary hospitals</p> <p>MoH to create national task group for auditing morbidities and mortalities to disseminating learning lessons to doctors &amp; patients</p>	<p>Woman and child health with training departments in all healthcare facilities OSOG</p>	<p>Within 1 year</p>
3. Delay in referring the patient to higher facility level	<p>Update the current guideline and address the referral issue in the guidelines</p>	<p>Woman and child Health department with of obstetrics and gynaecology departments in all hospitals.</p>	<p>2 months</p>
4. Communication failure between healthcare teams	<p>Hospitals to conduct communication skill workshop for newly joined staff</p>	<p>Training Department in hospitals</p>	<p>On regular basis</p>

<sup>1</sup> CME: Continuous Medical Education

Area	Action to be taken	Responsible department/person	Time frame
Related to woman herself			
1 Delay in seeking care	Conduct antenatal classes Conduct the health education sessions Create and distribute health education materials on ANC care and warning symptoms of obstetric emergency Encourage mothers to refer to the section on dangers signs and symptoms in the maternal held record	Department of Woman and Child Health with Department of Health Education	1 year
	Training health care providers in communication skills	Training departments	1 year and ongoing
2. Non-adherence to treatment/ Declining medications	Provide community nurses to follow up and educate mothers Provide leaflets to mothers about the treatment Improve counselling services to mothers at the healthcare facility Involve patient directly in taken decision about management	Department of Woman and Child Health with Department of Health Education	1 year

## Annex 27: Plan for future publications based on study results

Article title (tentative)	Aim of the article	Time frame and remarks
Maternal near-miss quality of care indicators and implementation: A systematic review	Present the findings of the systematic review on using MNM to assess the QoC; the methods of implementation and the indicators	The first manuscript to be reviewed and submitted by November-December 2019
National maternal near-miss survey and review in Oman	Describes the study methodology and main findings	January 2020
Causes of and contributory conditions to maternal near-miss in Oman	Presents the identified causes of MNM and contributory conditions	February 2020
MNM and quality of care: Findings of a national study in Oman	Presents the process and findings of assessment of QoC at the four review levels Describes identified associated factors and comparison of findings of different review panels	March 2020
Hypertensive disorders among women with MNM	Presents the findings relating to hypertensive disorders	April-May 2020
Obstetric haemorrhage among women with MNM	Presents the findings relating to obstetric haemorrhage	June-July 2020
Non-obstetric disorders among women with MNM	Presents the findings relating to non-obstetric complications	August-September 2020