BMJ Open

Surgical trends, outcomes and disparities in minimal invasive surgery for patients with endometrial cancer in England: a retrospective cohort study

Esther L. Moss ,[1] George Morgan,[2] Antony P. Martin,[2,3] Panos Sarhanis,[4] Thomas Ind[5,6]

To cite: Moss EL, Morgan G, Martin AP, *et al*. Surgical trends, outcomes and disparities in minimal invasive surgery for patients with endometrial cancer in England: a retrospective cohort study. *BMJ Open* 2020;**10**:e036222. doi:10.1136/bmjopen-2019-036222

► Prepublication history and additional material for this paper are available online. To view these files, please visit the journal online (http://dx.doi.org/10.1136/bmjopen-2019-036222).

Received 09 December 2019
Revised 01 July 2020
Accepted 03 July 2020

[1]Leicester Cancer Research Centre, University of Leicester, Leicester, UK
[2]HCD Economics, Warrington, UK
[3]Molecular and Clinical Pharmacology, University of Liverpool, Liverpool, UK
[4]Department of Gynaecology, North West London Hospitals NHS Trust, Harrow, UK
[5]Department of Gynaecological Oncology, Royal Marsden Hospital NHS Trust, London, UK
[6]Department of Obstetrics and Gynaecology, St George's University of London, London, UK

Correspondence to
Dr Esther L. Moss;
em321@le.ac.uk

ABSTRACT

Objective To examine surgical outcomes and trends in the implementation of minimally invasive surgery (MIS) use for endometrial cancer (EC).

Design Retrospective cohort study.

Setting English National Health Service hospitals 2011–2017/2018.

Population 35 304 patients having a hysterectomy for EC identified from Hospital Episode Statistics.

Methods Univariate and multivariate analyses compared MIS to open hysterectomy (OH) by assessing the association between demographic, clinical and hospital characteristics by using logistic regression. A propensity score was created, to control for confounding factors including demographics, clinical and hospital characteristics, from a logistic regression which enabled the inverse probability weighting of treatment to be applied in order to compare outcomes of treatment.

Main outcome measures The association between route of surgery on perioperative morbidity and mortality.

Results The MIS rate rose from 40.3% in 2011 to 68.7% in 2017/2018, however, there was significant geographical variation (p<0.001). The overall 90-day mortality was significantly higher with OH versus MIS (OR 0.34, 95% CI 0.18 to 0.62, p=0.0002). MIS rates were significantly lower in patients from the lowest socioeconomic group (LSEG) compared with patients from the highest group (HSEG) (55.4% vs 59.9%, p<0.01), and in the black population as compared with white and Asian populations (40.4% vs 58.6% and 56.0%, p<0.0001). When patients from LSEG and black patients were treated in hospitals with high MIS rates, the MIS rate increased close to that of the HSEG and white patients (81.0% and 74.1% vs 83.2% and 82.6%).

Conclusions Further investigation is needed to understand the barriers to MIS and improve access so that as many patients as possible can benefit from the reduced morbidity/mortality associated with MIS.

Strengths and limitations of this study

- ► The main strength of this study is that it is population based and the large number of procedures has enabled trends to be identified that may not have been seen in smaller datasets.
- ► Hospital Episode Statistics (HES) data only covers National Health Service (NHS)-funded care in England, therefore, data on hysterectomies undertaken outside of the NHS were not included in this study.
- ► The reliability of the coding might have changed over time although there was no evidence of changes in treatment coding or significant changes in the underlying study population.
- ► HES database reliably captures extensive amount of demographic, diagnosis and procedure outcomes, however, there is a lack of cancer stage information therefore it is possible some of the deaths may have been due to disease progression rather as a result of surgery.
- ► Not all deaths are captured in the HES database, only those which occurred in hospital which limits the death data captured in the HES database.

INTRODUCTION

There are estimated to be 382 069 new cases of endometrial cancer (EC) and 89 929 deaths worldwide in 2018.[1] The incidence of EC in the UK is rising,[2] attributed due to increasing rates of obesity, an ageing population and falling hysterectomy rates for benign disease.[3 4] Surgery remains the primary treatment option,[5] particularly for early-stage EC which is associated with a high overall survival rate. However, a less favourable benefit/risk profile for surgical outcomes exists in an elderly population with multiple comorbidities, where consideration is needed as to whether surgical morbidity and mortality would be higher than the risk of recurrence associated with non-surgical treatment options.[5]

The benefit of minimally invasive surgery (MIS) over traditional open surgery for EC has been firmly established with non-inferiority of survival and recurrence rates, and significantly lower levels of postoperative complications.[6–8] Initially studies were confined to early stage endometrioid cancers,[7 9] however, as the MIS skills of gynaecologists have developed enabling more extensive surgery, including pelvic/para-aortic lymph node dissection, this evidence has been extended to high-risk subtypes and more advanced disease.[10] As a result, MIS is the advocated as the preferred surgical route for the management of endometrial malignancy.[11 12]

The surgical management of EC in the UK is divided between satellite cancer units and central cancer centres, following the recommendations from the Calman Hine report in 1995.[13] Cancer units typically manage early-stage, low-grade cases and refer complex or higher stage/grade cases to their affiliated regional cancer centre. The adoption of MIS by the gynaecological oncology community is increasing, particularly for the treatment of EC,[14] however, national data from the USA in 2016 showed that the open hysterectomy (OH) was still the most common procedure rather than MIS.[15] Similarly, across the UK the uptake of MIS hysterectomy has been variable and significant regional differences exist.[16]

We performed an analysis using Hospital Episode Statistics (HES) for England.[17] Our primary objective was to examine trends in the implementation of MIS use in EC across England. Our secondary objectives were to examine predictors of uptake of MIS and to further explore the association between route of surgery on perioperative morbidity and mortality.

METHODS

Data source

Data were sourced from the HES database to conduct a retrospective cohort analysis from 2011–2017/2018.[17] No ethical approval was required for this study. The data were accessed by GM and analysed by GM and AM. Access to the data and HCD economics were funded by Intuitive Surgical. None of the clinicians involved in this study received any funding from Intuitive Surgical for this study. Intuitive Surgical did not have access to the data or involvement with the study design, data analysis and writing of the manuscript.

Cohort selection

From the HES database, an extracted dataset was created to only include patients that had specific Office of Population Censuses and Surveys Classification of Interventions and Procedures V.4.7 (OPCS-4.7) procedure codes which indicated they had a hysterectomy between the dates of October 2011 and December 2017. The specific OPCS-4.7 codes were: Q07.1, Q07.2, Q07.3, Q07.4, Q07.5, Q07.8, Q07.9, Q08.1, Q08.2, Q08.3, Q08.8 and Q08.9. The cohort of female patients was then restricted to be greater or equal to 18 years of age and further by using International Statistical Classification of Diseases and Related Health Problems, 10th Revision (ICD-10) primary diagnosis codes to identify patients where the indication was endometrial/uterine carcinoma or endometrial carcinoma in situ (ECIS) (complex atypical hyperplasia) (C540, C541, C542, C543, C548, C549, C55X and D070).

To classify the hysterectomy approach in terms of intention to treat, we used additional OPCS-4.7 codes. To identify laparoscopic hysterectomy (LH) the OPCS-4.7 codes were Y75.1, Y75.2, Y75.5, Y75.8, Y75.9, T43.9 and for robotic hysterectomy (RH) the OPCS-4.7 code Y75.3 was used. As a result, MIS is a combination of all the additional OPCS-4.7 codes. The remainder that did not have any of the additional OPCS-4.7 codes were classified based on the original procedure codes for the approaches of OH (Q07.1, Q07.2, Q07.3, Q07.4, Q07.5, Q07.8 and Q07.9) and vaginal hysterectomy (VH) (Q08.1, Q08.2, Q08.3, Q08.8 and Q08.9). In the cases where the OPCS-4.7 code Y71.4 (Failed minimal access approach converted to open) was recorded, and no MIS approach codes were reported alongside. A method to assign intention to treat as LH until the National Health Service (NHS) providers introduced robotic assisted surgery equipment and then classify intention to treat as robotic thereafter.

Patient characteristics

Demographic data that were collected included age, which was divided into 6 groups by 10-year intervals from the age of 50. Ethnicity data were collected and patients were grouped into Asian, black, other and white ethnicity.

The English Index of Multiple Deprivation (IMD)[18] for 2015 was collected to inform the socioeconomic deprivation of patients where a higher rank indicated a less deprived group and a lower rank indicated a more deprived group. The IMD score combines seven indicators (income, employment, health deprivation and disability, education, skills and training, barriers to housing and services, crime, and living environment), into a single deprivation index. The IMD ranks were then split into statistical quartiles to indicate whether the socioeconomic status was high (>25 083), intermediate (17 475–25083), low (9618–17474) or very low (<9618). Based on postcode of residence, each patient who received EC surgery was assigned to a lower super output area (LSOA) and this was mapped to an IMD rank calculated across the whole of England using this measure.

Comorbidities were examined using the Charlson Comorbidity Index (CCI)[19] and an additional list of other comorbidities were assessed using a list of ICD-10 codes.[20]

Hospital characteristics were evaluated for the region where the procedure took place and was classified into 10 groups (East, East Midlands, Greater London, Home Counties, North East, North West, South East, South West, West Midlands, Yorkshire). The hospital volume was also analysed as an annual mean across years (if more than 1 year was available) of all hysterectomies performed for EC/ECIS at the providers and grouped by statistical quartiles; high (>220), intermediate (71–220), low (70–21) and very low (0–20). In addition, each NHS hospital provider was classified by their MIS rate for hysterectomies performed on EC/ECIS and split into four groups:

very low 0%–25%, low 26%–50%, intermediate 51%–75%, high 76%–100%.

Outcomes

To analyse the trend of surgeries the number of procedures by each approach was assessed each year to see how practice had changed. The key surgical outcomes of interest were mortality and complications associated with each approach following the procedure. A list of complications were collated (ICD-10/OPCS-4.7 codes) for complication groups of gastrointestinal, wounds, infections, renal/genitourinary and endocrine, cardiovascular, pulmonary, neurological, haemorrhage, urinary tract, ureteric and other. These were assessed as perioperative (within the intervention admission) and at 90 days following intervention to ensure a long enough follow-up period to be assessed after surgery.[21] Perioperative outcomes included mortality, conversion to OH, recorded complications and length of stay. The 90-day outcomes also included in-hospital mortality and reported complications following the intervention. To assess disparities outcomes were assessed by regional variations at the patient level and additionally the provider level. Subgroup analysis was undertaken to compare the outcomes of high versus low socioeconomic groups and black ethnicity versus other ethnicities.

Statistical analyses

A descriptive analysis of patient characteristics and outcomes was performed. The different approaches (LH, RH, OH and MIS) were then compared by using t-test (for independent samples) and Wilcoxon rank-sum test (Mann-Whitney U test) for continuous variable and for categorical variables by using the χ^2 tests. Univariate and multivariate analyses compared MIS to OH and RH to OH by assessing the association between demographic, clinical and hospital characteristics by using a logistic regression. Based on the predicted probability, a propensity score was created from the logistic regression which included year of surgery, age groups, ethnicity, IMD rank groups, CCI group, region and provider volume. The predicted probabilities enabled the inverse probability weighting of treatment (IPTW) to be applied to balance observed confounders between the treatments.[22] To ensure balance of the measured covariate distribution between treatment groups, the standardised mean difference was assessed using a threshold for mean difference of 0.1.[23 24] Application of the IPTW was then used on comparing outcomes of treatment. Missing data of any of the propensity score variables were not imputed and patients with missing data were removed from propensity score matching. All descriptive and regression analyses were performed using Stata V.15.

Patient and public involvement

There was no patient or public involvement in the study planning or design.

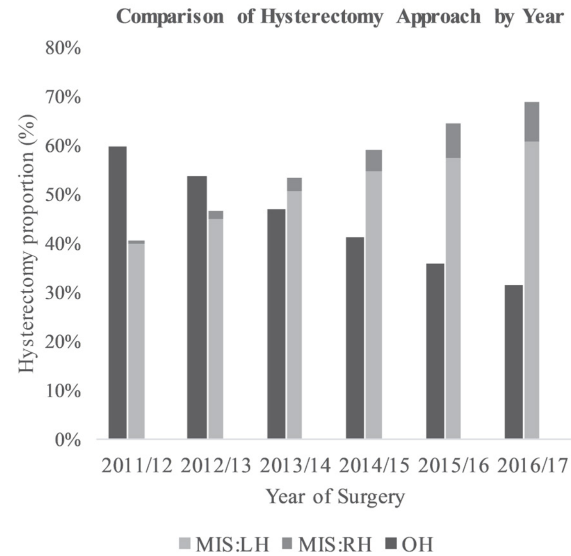

Figure 1 Route of hysterectomy by year. The route of surgery for endometrial cancer over time. LH, laparoscopic hysterectomy; MIS, minimally invasive surgery; OH, open hysterectomy; RH, robotic hysterectomy.

RESULTS

A total of 35 304 procedures were performed, 20 405 (57.8%) were MIS (LH 18 604 and RH 1801), 14 291 (40.5%) OH and 608 (1.7%) VH. Due to the low numbers the VH cases were not included in the analysis. The rate of MIS rose from 40.3% to 68.7% across the study period (p<0.001), with RH increasing from 0.7% in 2011/12% to 8.2% in 2016/17 (p<0.001), whereas the rate of OH fell from 59.7% in 2011/12 to 31.3% in 2016/17 (p<0.001) (figure 1). Lymph node dissection was performed in 18.4% of OH and 15.6% of MIS (14.6% LH, 25.3% RH) cases.

Table 1 presents the unadjusted and IPTW patient characteristics of those that received MIS or OH. Comparison of the unadjusted results of MIS and OH cases on patient characteristics identified that the OH group contained patients who were on average younger (66.1 vs 65.7 years, p=0.0052), of non-white ethnicity (p<0.001) and on average from a lower socioeconomic group (17 483 vs 16 788, p<0.001). There was no difference in the levels of obesity (24.0% vs 23.6%, p=0.504) between MIS and OH, however, there was a difference in the CCI score, (1.41 vs 1.52, p<0.001).

This was confirmed in the multivariate regression which found that a patient was more likely to receive MIS if the surgery was performed more recently, they were aged between 50 and 90 years and had the procedure undertaken in the North East or South West of England (p<0.001 for all: online supplementary appendix 1). Whereas a patient was more likely to receive OH if they attended a very low volume centre, were from a very low socioeconomic group, were of black or Other ethnicity, and located in the North West or West Midlands of England (p<0.001 for all: online supplementary appendix 2).

Table 1 Clinical and demographic characteristics by the cohorts of hysterectomy approach

	Unadjusted results					IPTW results				
	MIS hysterectomy (n=20405)		Open hysterectomy (n=14291)			MIS hysterectomy (n=16659)		Open hysterectomy (n=16624)		
Characteristics	No	%	No	%	P value	No	%	No	%	P value
NHS year of surgery										
2011/2012*	1127	6	1671	12		1305	8	1306	8	
2012/2013	2471	12	2829	20		2566	15	2561	15	
2013/2014	2971	15	2614	18		2677	16	2676	16	
2014/2015	3387	17	2361	17		2772	17	2782	17	
2015/2016	3500	17	1948	14		2635	16	2623	16	
2016/2017	4060	20	1852	13		2846	17	2848	17	
2017/2018*	2889	14	1016	7	<0.001	1858	11	1828	11	0.812
Age, years										
<50	1153	6	1082	8		1052	6	1056	6	
50–59	4317	21	3098	22		3568	21	3583	22	
60–69	7111	35	4672	33		5683	34	5664	34	
70–79	5693	28	3779	26		4541	27	4527	27	
80–89	2020	10	1540	11		1702	10	1682	10	
90>	111	1	120	1	<0.001	113	1	111	1	0.765
Ethnicity										
White	16453	81	11117	78		13272	80	13222	80	
Asian	649	3	499	3		539	3	544	3	
Black	251	1	365	3		289	2	285	2	
Other	3052	15	2310	16	<0.001	2559	15	2573	15	0.785
Socioeconomic group (IMD)										
High	5149	25	3291	23		4194	25	4201	25	
Intermediate	5015	25	3387	24		4142	25	4124	25	
Low	4924	24	3489	24		4134	25	4109	25	
Very low	4768	23	3703	26	<0.001	4188	25	4190	25	0.962
Charlson comorbidity group										
0	23	0	13	0		16	0	17	0	
1	13591	67	8405	59		10577	63	10550	63	
2	5429	27	4535	32		4767	29	4769	29	
≥3	1362	7	1338	9	<0.001	1299	8	1288	8	0.966
Region										
GLondon	2848	14	2184	15		2419	15	2421	15	
Yorks	1771	9	1220	9		1488	9	1512	9	
WestMid	1901	9	1672	12		1734	10	1739	10	
SouthWest	2751	13	1348	9		1981	12	1936	12	
SouthEast	2085	10	1451	10		1675	10	1645	10	
NorthWest	2909	14	2550	18		2624	16	2624	16	
NorthEast	1402	7	432	3		855	5	860	5	
Hcounties	1126	6	912	6		968	6	970	6	
EastMid	1650	8	1003	7		1289	8	1292	8	
East	1926	9	1497	10		1627	10	1625	10	
Missing	36	0	22	0	<0.001	–	–	–	–	0.957

Continued

Table 1 Continued

	Unadjusted results					IPTW results				
	MIS hysterectomy (n=20 405)		Open hysterectomy (n=14 291)			MIS hysterectomy (n=16 659)		Open hysterectomy (n=16 624)		
Characteristics	No	%	No	%	P value	No	%	No	%	P value
Provider volume										
High	12 725	62	8703	61		10 445	63	10 456	63	
Intermediate	7140	35	5102	36		5937	36	5894	35	
Low	288	1	191	1		232	1	231	1	
Very low	36	0	58	0		46	0	43	0	
Missing	216	1	237	2	<0.001	–	–	–	–	0.712

*NHS year 2011/2012 and 2017/2018 not full year.
IMD, Index of Multiple Deprivation; IPTW, inverse probability weighting of treatment; MIS, minimally invasive surgery; NHS, National Health Service.

Surgical morbidity and mortality

A significant difference was seen in the perioperative outcome of the different routes of surgery. The length of hospital stay was significantly longer for OH as compared with MIS (5.28 vs 2.32 days, p<0.001). The overall conversion rate to OH for MIS was 6.6%. IPW analysis identified that the only peri-operative complication that was not significantly higher with OH as compared with MIS was ureteric complications (p<0.001 for all other complications: table 2). The surgical complications requiring readmission/reintervention in 90 days were also significantly higher (9.6% vs 5.5%, p<0.001) in the OH cohort.

The overall mortality up to 90 days after surgery following IPTW was significantly higher with OH rather than MIS (OR 0.34; 95% CI 0.18 to 0.62; p=0.0002: table 2). This relationship was accentuated when comparing RH versus OH (OR 0.04; 95% CI 0 to 0.27; p<0.001). The patients who died in the 90-day period following surgery were older (70.6 vs 70.4 years, p=0.0012) and had more comorbidities, in particular diabetes (p=0.024) hypertension (p=0.018), renal failure (p=0.001) and angina (p=0.017), compared with patients who did not die.

Table 2 Comparison of mortality and complications at intervention between MIS and OH cohorts

	Unadjusted results						IPTW results					
	MIS		OH			MIS versus OH	MIS		OH			MIS versus OH
	No	%	No	%	P value	OR (95% CI)	No	%	No	%	P value	OR (95% CI)
Death (intervention)	9	0	18	0	0.007	0.35 (0.14 to 0.82)	8	0	25	0	0.003	0.32 (0.12 to 0.73)
Death (overall)*	17	0	44	0	<0.001	0.27 (0.14 to 0.48)	15	0	44	0	<0.001	0.34 (0.18 to 0.62)
Any complication (intervention)	4305	21	4012	28	<0.001	0.54 (0.51 to 0.57)	3503	21	4725	28	<0.001	0.67 (0.64 to 0.71)
Specific complications (intervention)												
Gastrointestinal	1637	8	1185	8	<0.001	0.61 (0.57 to 0.66)	1275	8	1479	9	<0.001	0.85 (0.79 to 0.92)
Wounds	325	2	679	5	<0.001	0.20 (0.17 to 0.23)	276	2	783	5	<0.001	0.34 (0.30 to 0.39)
Infections	360	2	815	6	<0.001	0.16 (0.14 to 0.19)	296	2	913	5	<0.001	0.31 (0.27 to 0.36)
Urinary	623	3	786	5	<0.001	0.26 (0.24 to 0.29)	514	3	899	5	<0.001	0.56 (0.50 to 0.62)
Ureteric	6	0	8	0	0.005	0.25 (0.07 to 0.82)	4	0	8	0	0.247	0.50 (0.11 to 1.86)
Cardiovascular	1255	6	1162	8	<0.001	0.30 (0.27 to 0.32)	1047	6	1340	8	<0.001	0.77 (0.70 to 0.83)
Pulmonary	305	1	587	4	<0.001	0.13 (0.11 to 0.15)	262	2	676	4	<0.001	0.38(0.33 to 0.44)
Neurological	84	0	111	1	<0.001	0.18 (0.14 to 0.24)	77	0	120	1	0.002	0.64 (0.47 to 0.86)
Haemorrhage	199	1	270	2	<0.001	0.17 (0.14 to 0.20)	169	1	310	2	<0.001	0.54 (0.44 to 0.65)
Other	736	4	646	5	<0.001	0.22 (0.20 to 0.25)	593	4	786	5	<0.001	0.74 (0.67 to 0.83)

*Death (overall) Includes death at intervention and deaths reported 90 days after intervention.
IPTW, inverse probability weighting of treatment; MIS, minimally invasive surgery; OH, open hysterectomy.

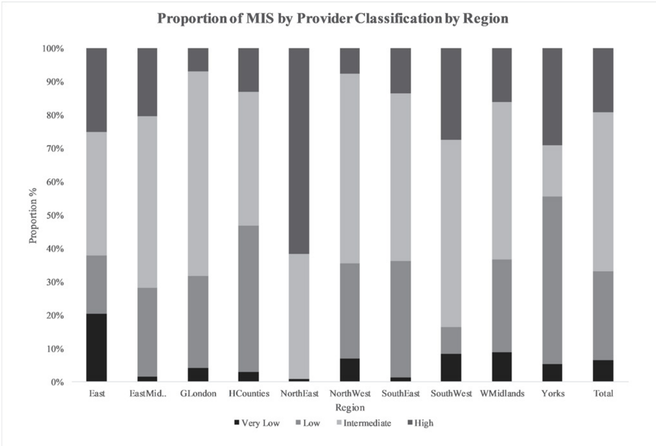

Figure 2 Providers MIS rate classification by region. The proportion, by region, of providers classified as having high, intermediate, low and very low MIS rates (very low 0%–25% MIS rate, low 26%–50% MIS rate, intermediate 51%–75% MIS rate, high 76%–100% MIS rate). MIS, minimally invasive surgery.

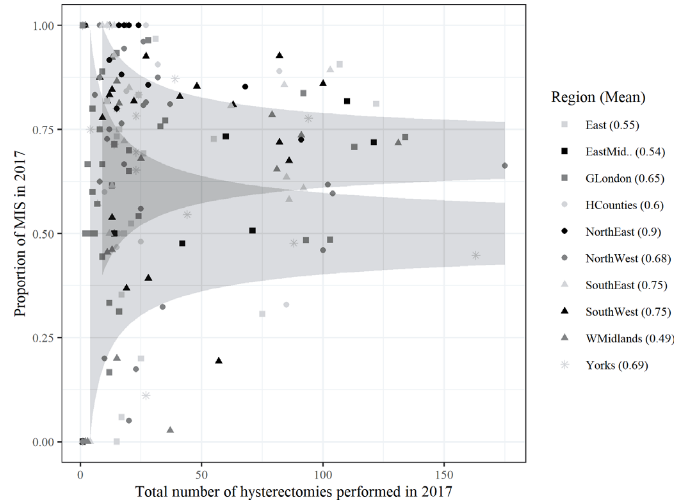

Figure 3 Funnel plot of MIS rate and number of cases performed for 2017. The proportion of hysterectomies performed by MIS by the total number of hysterectomies for each provider that performed at least one hysterectomy in 2017. Each provider is also classified by their region and an average value for each region is plotted. two thresholds are for 50% and 70% MIS rate. MIS, minimally invasive surgery.

Regional variation

The MIS rate increased year on year across all regions, however, the uptake varied significantly between geographical regions (p<0.001; table 1). Very low volume centres (<20 cases per year) had a significantly lower MIS rate compared with the other quartiles, 37.5% vs 58.9% for low, 56.7% intermediate and 58.9% for high, (p<0.05 for all). Provider level analysis showed only 55 centres had high MIS levels for EC (>76.0% MIS rate) and there was a large disparity between regions (figure 2). Over time the age of the patients undergoing MIS increased and by 2017 was the median age was higher than for OH cases, with the greatest increase being seen in the high MIS providers. The CCI of patients undergoing surgery (any route) between 2011 and 2018 also increased year on year, however, at high and intermediate MIS centres the ratio between CCI of OH and MIS patients became smaller (1.06 in 2011 to 1.02 in 2017). In addition, there was great variability across providers and regions as to the proportion of MIS implemented, with 78% of providers achieving a 50% threshold but only 56% passing a 70% threshold (figure 3).

Disparity in MIS rates

Disparity was seen in the MIS rates in patients from the lowest socioeconomic group as compared with patients from the highest group (55.4% compared with 59.9%, p<0.01). Patients from this group were younger compared with patients in the high socioeconomic group(64.3 vs 67.0 years, p<0.01) but had a higher level of comorbidities (1.56 vs 1.39, p<0.01). When patients from the lowest socioeconomic group were treated in high MIS centres the MIS rate increased to 81.0%, close to the rate in patients from the highest socioeconomic group 83.2%.

Black patients undergoing surgery were significantly younger than patients from other ethnic groups (63.7 vs 66.0, p<0.001), were mainly located in more deprived areas (85.9% in low or very low socioeconomic status) and had more comorbidities as compared with the overall population cohort (1.65 vs 1.45, p<0.001). The MIS rates were significantly lower in the black population as compared with the white and Asian populations, 40.4% as compared with 58.6% and 56.0%, respectively (p<0.001). A significantly higher percentage of white patients (21.2%) attended high MIS centres as compared with Asian or black patients (7.8% and 4.7%, respectively), however, when black patients underwent surgery at a high MIS provider, their MIS rate increased to 74.1% (figure 4).

DISCUSSION

Main findings

We have identified significant disparities in the rates of MIS in England forpatients undergoing hysterectomy in the NHS for EC/ECIS. Patients from the lowest socioeconomic group and of non-white ethnicity and were significantly less likely to undergo MIS as compared with white patients from more socially affluent areas. The difference in MIS rates was reduced when patients underwent surgery at high MIS providers, indicating that patient's geographical location and local facilities to provide MIS is a factor in route of surgery for EC.

There are confounding factors that could help to explain the difference between the populations. The CCI score was significantly higher in the lower socioeconomic and black populations, which could have resulted in them being not suitable for MIS. Black ethnicity is known to be associated with a higher incidence and size of uterine fibroids as compared with white women,[25] which again could have contribute to a higher OH rate by making MIS

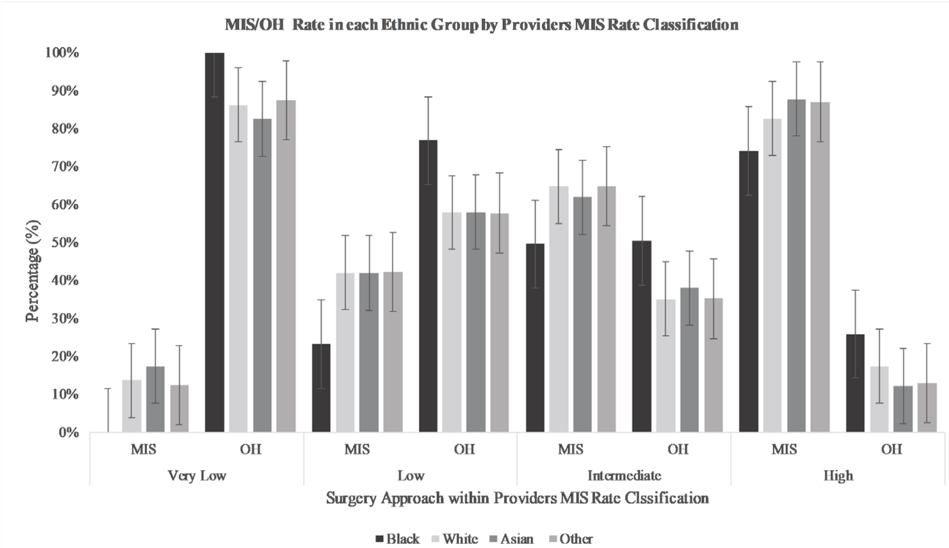

Figure 4 MIS/OH rate at patient ethnicity by providers MIS rate classification. Comparison of the percentage split between MIS and OH at each of the MIS rate classifications by patient ethnicity (very low 0%–25% MIS rate, low 26%–50% MIS rate, intermediate 51%–75% MIS rate, high 76%–100% MIS rate). MIS, minimally invasive surgery; OH, open hysterectomy.

not technically feasible, and non-white ethnicity has been identified as a risk factor for conversion to open surgery.[26] The previous abdominal surgery rate is also not well recorded in the HES data, therefore, patients who have undergone extensive surgery previously would also not have been appropriate for MIS. Similarly, the presence of fibroids that would preclude MIS is not recorded on HES and would depend on the size/location of the fibroid as well as the experience of the surgical team in performing MIS. However, if these were the only reasons for the disparity it does not explain why the MIS rate increases in patients from the lowest socioeconomic group or of black ethnicity undergoing surgery at high MIS providers.

Unlike in cervical cancer,[27 28] there has not been shown to be a difference in long-term oncological outcome of the use of MIS as compared with OH in EC.[7] The perioperative death rate associated with OH is known to be significantly higher as compared with MIS, however, we have shown the magnitude of the difference is much greater than previously reported. Wright *et al*, in his analysis of 6304 patients from the SEER database (2006–2011) identified an OR of death by 30 days for OH as compared with MIS of 0.57 (95% CI 0.34 to 0.95),[22] whereas in our study a threefold increase risk of death was found with OH compared with MIS (OR 0.34; 95% CI 0.18 to 0.62).

The patients who died following surgery were older and more comorbid than the population that survived and as such may have been deemed unsuitable for MIS, although this could only be determined on an individual case by case basis. The age of patients undergoing MIS has increased across all regions since 2012 indicating that surgical teams have gained experience and are aware of the benefits and evidence supporting the use of MIS in the elderly population.[29] Patient comorbidities, as determined by CCI, do however appear to influence MIS rates, with only the high/intermediate MIS providers demonstrating a rise in the CCI level of their cases over time, suggesting that one reason why there is such a high proportion of MIS cases in some centres is because they undertake cases MIS that other centres may deem unsuitable or too high risk for MIS. This highlights the challenges of operating on patients with medical comorbidities since surgical risk is not confined to the technicalities of the surgery but encompasses the patient's entire perioperative care, including preoperative optimisation, anaesthetic procedure and postoperative mobilisation, nutrition and recovery. In particular, the anaesthetic experience and high-dependency unit support to undertake challenging cases MIS may be lacking in hospitals only performing a small number of EC/ECIS cases per year, which may in turn contribute to the significantly lower MIS rates in these centres.[30]

Sharing expertise and providing support and mentorship for low MIS providers through local cancer centre/unit networks could help increase the overall MIS rates, however, the introduction of a national best practice target in England may help to focus resources on this population so that patients from all backgrounds and areas can benefit. MIS rates for EC have been proposed a quality indicator,[31] and the target set in Scotland has been raised from 50% in 2014 to 70% in 2018, reflecting the change in clinical practice.[32] We have shown that in 2017 only 56% of providers reached the 70% threshold, therefore, much greater support for gynaecologists and their surgical teams will be needed in order for the majority of providers in England to achieve this target. Although the 95% MIS rate achieved in Denmark[33] would suggest that this target could be set even higher, thereby impacting on the significantly higher mortality seen with OH, and act as an incentive for individual providers to analyse their cases and strive to increase their proportion of MIS procedures further. If improvements cannot be made in the low

MIS rate seen in some of the very low volume providers it does raise the argument as to whether a minimum annual caseload should be introduced for hospitals, with further centralisation of EC surgical management to larger providers, in order to increase access to MIS. Referral to larger providers may impact on overall MIS rates, however, it could result in greater disruption and burden to the patient rather than being treated by their local provider since, as already discussed, this population may be elderly and comorbid.

Strengths and limitations

The main strength of this study is that it is population based and the large number of procedures has enabled trends to be identified that may not have been seen in smaller datasets. It should be noted that HES data only covers NHS-funded care in England, therefore, data on hysterectomies undertaken outside of the NHS were not included in this study. Despite its limitations, in particular the lack of cancer stage information and potential recording or adjudication errors, the ethnicity data in HES data are known to be reliable and match the UK population.[32] The lack of staging data means that it is not possible to identify the small proportion of cases that would have undergone more extensive open cytoreductive surgery, which would be associated with a substantially higher morbidity/mortality rate than an MIS staging procedure. Cytoreductive procedures would only have taken place at designated cancer centres due to the location of specialist gynaecological oncology surgeons, and therefore, such procedures will not have impacted the rate of open surgery or outcomes from cancer units. Despite a lack of stage data the pelvic lymphadenectomy rate is known and has been included, which was comparable across the groups (18.4% in OH, 14.6% in LH and 25.3% in RH).

The reliability of the coding might have changed over time although there was no evidence of changes in treatment coding or significant changes in the underlying study population. Another limitation relates to the sensitivity of IMD quintiles matched to each LSOA. Moreover, within each LSOA, there may be significant variation in terms of deprivation and therefore future research should assess deprivation at an individual level

Confining the survival analysis to 90 days following surgery aimed to capture procedure related rather than disease-specific deaths, although since stage data are not available, it is possible some of the deaths may have been due to disease progression rather as a result of surgery.

Interpretation

Disparities exist in the use of MIS for the treatment of EC/ECIS in England. Further investigation of patient-level data, preference elicitation studies and qualitative research are needed to understand the potential barriers to MIS in clinical practice and to improve access so that as many patients as possible can benefit from the reduced morbidity and mortality associated with MIS.

Acknowledgements We would like to acknowledge the contributions from Thomas Burke, Gabriel Pedra and from HCD Economics who assisted in the conduct of this study. We would like to thank Harvey Walsh for facilitating access to Hospital Episode Statistics Data via a Standard Extract Re-use Agreement issued by the Health and Social Care Information Centre 2018.

Contributors ELM, TI, GM and AM contributed to the conceptualisation and study design. Data analysis and interpretation was performed by ELM, TI, GM, AM and PS. Figures and tables creation was performed by ELM, GM and AM. All authors were involved in the writing or review of the manuscript and approved the final version.

Funding HCD economics were funded by Intuitive Surgical. None of the clinicians involved in this study received funding from Intuitive Surgical.

Disclaimer Intuitive Surgical did not have any involvement with the study design, data analysis and writing of the manuscript.

Competing interests ELM and TI perform Da'Vinci robotic gynaecological surgery (Intuitive Surgical) and are members of the British and Irish Association of Robotic Surgeons (BIARGS), which is supported by Intuitive Surgical and other robotics/laparoscopic companies to hold education/training events. ELM has been awarded research grants from Intuitive Surgical and Hope Against Cancer for unrelated studies. TI has done two days paid consultancy work for Medtronic. GM and AM from HCD Economics were funded by Intuitive Surgical.

Patient consent for publication Not required.

Ethics approval The HES database is managed by NHS Digital and is available for research without ethical approval.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data may be obtained from a third party and are not publicly available. Data analysed in this study is available through Hospital Episode Statistics (HES).

ORCID iD

Esther L. Moss http://orcid.org/0000-0002-2650-0172

REFERENCES

1 Bray F, Ferlay J, Soerjomataram I, *et al*. Global cancer statistics 2018: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. *CA Cancer J Clin* 2018;68:394–424.
2 Cancer Research UK. Uterine cancer statistics | cancer research UK. Available: https://www.cancerresearchuk.org/health-professional/cancer-statistics/statistics-by-cancer-type/uterine-cancer [Accessed 21 Aug 2019].
3 Crosbie E, Morrison J. The emerging epidemic of endometrial cancer: time to take action. In: Tovey D, ed. *Cochrane database of systematic reviews*. Chichester, UK: John Wiley & Sons, Ltd, 2014.
4 Reid PC, Mukri F. Trends in number of hysterectomies performed in England for menorrhagia: examination of health episode statistics, 1989 to 2002-3. *BMJ* 2005;330:938–9.
5 Podzielinski I, Randall ME, Breheny PJ, *et al*. Primary radiation therapy for medically inoperable patients with clinical stage I and II endometrial carcinoma. *Gynecol Oncol* 2012;124:36–41.
6 Asher R, Obermair A, Janda M, *et al*. Disease-free and survival outcomes for total laparoscopic hysterectomy compared with total abdominal hysterectomy in early-stage endometrial carcinoma: a meta-analysis. *Int J Gynecol Cancer* 2018;28:529–38.
7 Galaal K, Bryant A, Fisher AD, *et al*. Laparoscopy versus laparotomy for the management of early stage endometrial cancer. *Cochrane Database Syst Rev* 2012;9:CD006655.
8 Walker JL, Piedmonte MR, Spirtos NM, *et al*. Laparoscopy compared with laparotomy for comprehensive surgical staging of uterine cancer: gynecologic oncology group study LAP2. *J Clin Oncol* 2009;27:5331–6.
9 Janda M, Gebski V, Brand A, *et al*. Quality of life after total laparoscopic hysterectomy versus total abdominal hysterectomy for stage I endometrial cancer (LACE): a randomised trial. *Lancet Oncol* 2010;11:772–80.

10 Nieto VL, Huang Y, Hou JY, *et al*. Use and outcomes of minimally invasive hysterectomy for women with nonendometrioid endometrial cancers. *Am J Obstet Gynecol* 2018;219:463.e1–463.e12.
11 Sundar S, Balega J, Crosbie E, *et al*. BGCS uterine cancer guidelines: recommendations for practice. *Eur J Obstet Gynecol Reprod Biol* 2017;213:71–97.
12 NICE. Interventional procedure overview of laparoscopic hysterectomy (including laparoscopic total hysterectomy and laparoscopically assisted vaginal hysterectomy) for endometrial cancer, 2010. Available: https://www.nice.org.uk/guidance/ipg356/documents/laparoscopic-hysterectomy-including-laparoscopic-total-hysterectomy-and-laparoscopic-assisted-vaginal-hysterectomy-for-endometrial-cancer-overview2 [Accessed 21 Aug 2019].
13 Whitehouse M. A policy framework for commissioning cancer services. *BMJ* 1995;310:1425–6.
14 Mabrouk M, Frumovitz M, Greer M, *et al*. Trends in laparoscopic and robotic surgery among gynecologic oncologists: a survey update. *Gynecol Oncol* 2009;112:501–5.
15 Mannschreck D, Matsuno RK, Moriarty JP, *et al*. Disparities in surgical care among women with endometrial cancer. *Obstet Gynecol* 2016;128:526–34.
16 Madhvani K, Curnow T, Carpenter T. Route of hysterectomy: a retrospective, cohort study in English NHS hospitals from 2011 to 2017. *BJOG* 2019;126:795–802.
17 NHS Digital. Hospital episode statistics (HES). Available: https://digital.nhs.uk/data-and-information/data-tools-and-services/data-services/hospital-episode-statistics [Accessed 6 Aug 2019].
18 Government D for C and L. The English index of multiple deprivation (IMD) 2015-Guidance, 2015. Available: https://www.gov.uk/government/statistics/english-indices-of-deprivation-2015 [Accessed 22 Feb 2019].
19 Quan H, Li B, Couris CM, *et al*. Updating and validating the Charlson comorbidity index and score for risk adjustment in hospital discharge Abstracts using data from 6 countries. *Am J Epidemiol* 2011;173:676–82.
20 Ma C, Crespin M, Proulx M-C, *et al*. Postoperative complications following colectomy for ulcerative colitis: a validation study. *BMC Gastroenterol* 2012;12:39.
21 Adam MA, Turner MC, Sun Z, *et al*. The appropriateness of 30-day mortality as a quality metric in colorectal cancer surgery. *Am J Surg* 2018;215:66–70.
22 Wright JD, Burke WM, Tergas AI, *et al*. Comparative effectiveness of minimally invasive hysterectomy for endometrial cancer. *J Clin Oncol* 2016;34:1087–96.
23 Austin PC. Balance diagnostics for comparing the distribution of baseline covariates between treatment groups in propensity-score matched samples. *Stat Med* 2009;28:3083–107.
24 Zhang Z, Kim HJ, Lonjon G, *et al*. Balance diagnostics after propensity score matching. *Ann Transl Med* 2019;7:16.
25 Kjerulff KH, Langenberg P, Seidman JD, *et al*. Uterine leiomyomas. Racial differences in severity, symptoms and age at diagnosis. *J Reprod Med* 1996;41:483–90.
26 Jones N, Fleming ND, Nick AM, *et al*. Conversion from robotic surgery to laparotomy: a case-control study evaluating risk factors for conversion. *Gynecol Oncol* 2014;134:238–42.
27 Melamed A, Margul DJ, Chen L, *et al*. Survival after minimally invasive radical hysterectomy for early-stage cervical cancer. *N Engl J Med* 2018;379:1905–14.
28 Ramirez PT, Frumovitz M, Pareja R, *et al*. Minimally invasive versus abdominal radical hysterectomy for cervical cancer. *N Engl J Med* 2018;379:1895–904.
29 Uccella S, Bonzini M, Palomba S, *et al*. Laparoscopic vs. open treatment of endometrial cancer in the elderly and very elderly: an age-stratified multicenter study on 1606 women. *Gynecol Oncol* 2016;141:211–7.
30 Srivastava A, Niranjan A. Secrets of safe laparoscopic surgery: anaesthetic and surgical considerations. *J Minim Access Surg* 2010;6:91–4.
31 Bonte A-S, Luyckx A, Wyckmans L, *et al*. Quality indicators for the management of endometrial, cervical and ovarian cancer. *Eur J Surg Oncol* 2019;45:528–37.
32 Taskforce SC, Scotland HI. *Scottish cancer taskforce cutaneous melanoma clinical quality performance indicators: endometrial cancer - 2014*, 2016.
33 Jørgensen SL, Mogensen O, Wu C, *et al*. Nationwide introduction of minimally invasive robotic surgery for early-stage endometrial cancer and its association with severe complications. *JAMA Surg* 2019;154:530.