PAEDIATRIC HEAD INJURY

DECISIONS

IN

THE ACCIDENT AND EMERGENCY DEPARTMENT

M.D. THESIS

1997

MARIE T. BROOKES

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Volume I

PAEDIATRIC HEAD INJURY

DECISIONS

IN

THE

ACCIDENT AND EMERGENCY DEPARTMENT

This Thesis is submitted in accordance with the Regulations of

The University of Liverpool for the Degree of Doctor of Medicine

Marie Therese Brookes, MB., ChB., D.F.M., FFAEM

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Declaration

This Thesis is the result of my own work. The material has not been, nore is currently being submitted, in whole or in part, for any other degree or qualification.

The work was undertaken at Monklands District General Hospital, where the author was a full time Consultant in Accident & Emergency Medicine.

Signed:

Marie T. Brookes
August 1997

Dedication

This Thesis is dedicated to my late mother, Agnes Cox, whose sacrifices made possible my medical education at the University of Liverpool, and to the children who may benefit from its submission.

Acknowledgement

I wish to acknowledge the assistance of the doctors and nurses in all the Accident and Emergency Units, who made the Study possible, and in particular the doctors who provided liaison between their hospital and myself. Valuable assistance was given by Dr. John Scott and Dr. Iain Brown in the transfer of data to the mainframe computer and in the recovery of patient records and xrays.

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My colleague Dr. Ian McLaren, was supportive in the time I dedicated to this work.

To all those too numerous to mention who made a contribution, and to my family for their tolerance, I am most grateful.

Marie T. Brookes

CONTENTS

VOLUME I

LIST OF ABBREVIATIONS

#	Skull Fracture
ACLS	Advanced Cardiac Life Support
A.H.	Alder Hey Hospital (Royal Liverpool Childrens Hospital)
ATLS	Advanced Trauma Life Support
CMO	Casualty Medical Officer
CO	Casualty Officer
E.P.	Emergency Physican
G.C.S.	Glasgow Coma Scale/Score
GRI	Glasgow Royal Infirmary
H+	Headache present
H-	Headache absent
H+V+	Headache and Vomiting present
H-V-	No headache or vomiting
HRI	Hull Royal Infirmary
MDGH	Monklands District General Hospital
N	Number
NAI	Non accidental Injury
Neg-	Negative
No	None
N/R	Not recorded
NXR	Number of xrays
N#	Number of fractures
PGH	Poole General Hospital
PLSG	Paediatric Life Support Group
Pos+	Positive
Pts	Patients
RACH	Royal Aberdeen Children's Hospital
Rad	Radiologist
Reg	Registrar
SA	Statistical Analysis
SHO	Senior House Officer
S Reg	Senior Registrar
V+	Vomiting present
V-	Vomiting absent
XR	Skull xray

DEATH WILL BE NO STRANGER TO THE PHYSICIAN WHO ACTS UNDER THE CONCEPT THAT MINOR HEAD TRAUMA WARRANTS MINOR CONCERN

Vogel

A. DECISIONS IN THE ACCIDENT & EMERGENCY DEPARTMENT

Head injury is common. It represents 10-18% of the workload of Accident & Emergency Departments in the United Kingdom, where it has been estimated that one million patients with head trauma attend annually. A hospital providing a 24 hour Accident & Emergency Service, serving a population of 200,000 might therefore expect to receive 4,000 - 5,000 patients each year with a head injury. Between 30% and 50% of these will be children.

The responsibility for the initial management of the head injured patient varies in different countries. In the United Kingdom policies and protocols may be modified, to take account of regional and local facilities, and the specialty of doctors involved in initial care. Organisation of trauma and head injury services may expose differences, both nationally and locally, which make precise comparisons difficult.

In the United Kingdom, Neurosurigcal Services are provided on a Regional basis, and it is not anticipated, despite the current audit of major trauma management that significant changes, will be widely made in the next decade. The majority of patients who have sustained a head injury will continue to attend in Accident & Emergency Departments. Their staff will receive, assess, investigate and in cases of severe or multiple injury resuscitate the victim. Medical staff will make decisions regarding discharge, admission to hospital and transfer to Neurosurgical Units or Intensive Care.

Eighty five percent of patients with head injury, 850,000 approximately of those presenting at hospital are discharged by Casualty Medical Officers each year. The burden of responsibility is often underestimated, and certainly understated by many of those clinicians and others who do not have to accept it. Junior medical staff are faced with decisions in difficult circumstances, often without the benefit of experience or prior training, and in the absence of senior support and supervision. This is particularly so in the out of hours situation. Paradoxically the more obvious the severity of the head injury, the less difficult is the junior doctor's task, and the greater the clinical expertise available to assist. Within the group of patients with serious head trauma will be the 2%-5% transferred to Neurosurgical Units. Some will have sustained severe primary cerebral insult, or have an identified or suspected complication. Less readily selected by the inexperienced doctor, will be the patient, who appears well, but who is at risk of developing a serious or life threatening complication, requiring urgent neurosurgical intervention.

In Neurosurgical Units expertise and resources are supported by Specialised Intensive Care facilities, and sophisticated non invasive and invasive diagnostic equipment, and monitoring devices. It is essential that patients transferred to Neurosurgical Units are those who require, and will receive maximum benefit from such access. The selection of patients, is the responsibility of the specialists in the Primary Receiving Unit or Hospital, in consultation with Neurosurgical colleagues. Increasingly, the primary specialist will be the Accident & Emergency Consultant. The development of the specialty of Accident & Emergency Medicine over the past 30 years, and the increasing number of Units with one or more full time Accident & Emergency Consultants in post, has resulted overall in improved care of patients. In many areas there has been an increase in commitment to head injury management by such consultants. This may include responsibility for a short stay observation facility, or more formal non-neurosurgical head injury wards. Opportunities are thereby provided for fruitful liaison between consultants, and their neurosurgical colleagues. Protocols can be agreed, efficient systems of communication established, and safe Transfer Systems devised for the seriously traumatised victim. This can only benefit the patient at whatever age.

Teaching and training of junior medical staff in each of the specialties, and reciprocal arrangements for career grade training can be improved.

Co-operation between the two specialties will provide access to clinical information in the Accident Unit and even in the prehospital setting, at a very early stage following trauma. It should ensure systems of care to eliminate or reduce the risks of secondary insults to the brain following upon the primary trauma. Data recovered may assist in protocols for immediate care and management in the Accident & Emergency Departments. The resulting benefits should reduce the mortality and morbidity following the accident, by securing appropriate interventions and resuscitative procedures. Delays to neurosurgical intervention, with the serious and avoidable consequences reported in the past should be prevented

Clinical information available, but unrecorded or untapped in the Accident & Emergency record, may prove valuable in providing guidance for Casualty Officers in the decision making process. It is hoped that some of the data recorded in this Thesis will make such a contribution.

Paediatric Services in the Accident & Emergency Department

The majority of Accident & Emergency Departments in the United Kingdom, of necessity see large numbers of children, alongside adult patients, and head injuries are a substantial component of this workload. Accident & Emergency Departments dedicated exclusively to children are exceptional, and have the benefit of staffing, both medical and nursing, trained to meet all the needs of the sick or injured child. The environment is designed and the resources matched to the ideal standards of care of the child in hospital. Some have dedicated consultants in Accident & Emergency Medicine. To assess the benefits and the contrasts with the general Accident & Emergency Department, two such Specialist Hospitals were selected for this Study at Liverpool and Aberdeen.

Over the years, concern has been expressed regarding the facilities afforded to young patients in mixed Units The frequency with which children sustain head injury, their different patterns of response to trauma, and their specific needs as children, present a challenge to doctors involved in, and responsible for their initial medical care. I became more acutely aware of these potential deficiencies, when in 1984 I conducted a survey of head injured patients attending in Monklands District General Hospital. Data on 3,424 patients was collected for analysis. 1,720 - 50% proved to be in the paediatric age group. This provided the stimulus to examine in greater detail, the causes, nature, clinical features of injury, investigations undertaken and decisions subsequently made. It was intended to assess the quality of care offered and to remedy any deficiencies identified.

Criticism of resources provided for children, and the absence of even basic information on the demands they make on Accident & Emergency Services had been reported by Jackson. This followed a survey undertaken by the British Paediatric Association. His criticism provided the impetus to undertake a Study which would support, or hopefully refute his statements. Assessment of the care given to children in mixed adult/paediatric departments, and exclusively paediatric units would be made. From the basic foundation, the idea of the co-ordinated Multi-Centre Study evolved.

B. AIMS OF THE STUDY

1. To identify the clinical features, and to study the methods of assessment, and the investigations undertaken and their value in the decision making process.
2. To examine in detail, decisions taken by doctors in the Accident & Emergency Department on the child who had suffered recent trauma to the head.
3. To recover data which might allow the formulation of Guidelines similar to those produced for adults which would lead to an accepted concept of good clinical practice. This would lend reassurance to junior doctors, and provide a more disciplined approach to management decisions. When validated such Guidelines would have medicolegal benefit.
4. To compare and contrast care offered to children in exclusively Paediatric A&E Units in Dedicated hospitals, to that provided in the adult/mixed units.

In addition, such a detailed survey would provide information on medical staffing, resources available or required in a 24 hour emergency service, receiving children.

The contribution made by paediatricians to the care of children in Accident & Emergency Departments was not known.

Publications relating to the attendance of head injured patients in the Primary Care Service, Casualty Units and Accident & Emergency Departments are much smaller in number than those emanating from in patient services, Neurosurgical Units and Intensive Care and Trauma Centres. This is understandable, because such units are dealing with more severe injuries. The deficiency was first identified by Field in his monograph on the epidemiology of head injury. Since that time studies have been undertaken, notably by investigators from the Institute of Neurological Sciences in Glasgow. The Scottish Head Injury Management Group provided the first comprehensive report on Accident & Emergency Departments. Subsequently various aspects of head injury management have been reported from Accident & Emergency Departments. Some authors have reported on specific conditions presenting in Accident & Emergency Departments. Other reports have concentrated on the use of investigative procedures.

Papers have also been published from North American centres in recent years. In attempting to review the literature in the complex field of head trauma, and particularly head trauma in children, I have identified a failure to define and standardise terms.

Head Injury defined as trauma to the head, and brain injury are not necessarily synonymous. Head trauma may extend over a spectrum from the most minor to the life threatening. Publications have been related to severity, (subject to a variety of classifications), to the health care location and to causes e.g. motor vehicle, sports injuries etc.

Most studies have been retrospective, and suffer from the acknowledged limitations of that method. Systems of analysis vary. In some studies, children have been included with, but not identified separately from adults. All these factors make comparisons difficult and conclusions perhaps insecure? In severe trauma, head injury may occur in isolation or in combination with other life threatening injuries, which significantly affect, both the outcome and management.

C. PATIENTS AND METHODS/STATISTICAL ANALYSIS

Methods were formulated, data definitions identified, and statistical analyses agreed, Appendix A.

Prospective data was recorded on 5593 children, attending in the six Accident and Emergency Departments using a printed proforma. The information was selected to meet the Aims of the Study, and to identify and evaluate decisions taken by doctors on the initial assessment of the head injured child.

The procedures followed for data collection and the precise definitions to be applied was issued to the doctors – Appendix B.

The information collected included Attendance patterns, age and sex, the causes and mechanisms of injury, a history of loss of consciousness, its duration and any impairment of conscious level as assessed on the Paediatric Coma Scale.

Scalp injury manifested visibly or on palpation confirmed trauma to the head and its site on the skull.

Symptoms following head trauma included headache and vomiting.

Pre and post traumatic seizures were noted. The confirmation of pyrexia and an evaluation of its cause was included.

The assessing doctors had access to diagnostic imaging in the form of skull radiology. Computerised brain scanning, though provided in some of the units was not available to the A&E Staff. All CT Brain Scans were undertaken after transfer to the relevant Neurosurgical Unit.

The results of skull xrays influenced the doctors decisions on further treatment, and with other features and symptoms, the disposal. This included admission for observation, for treatment, further investigations and transfer to neurosurgery.

Unusual complications which were rare, were observed in admitted patients.

The incidence of intracranial haematoma was derived from neurosurgical records and its association with skull fracture was specifically sought. The limited access to CT Brain Scans prevented any assessment of non-neurosurgical abnormalities.

Outcome at one month was related to physical disability only.

D. SUMMARY AND CONCLUSIONS

THE MONKLANDS COORDINATED PAEDIATRIC HEAD INJURY STUDY

Summary and Conclusions

The prospective study of almost 6,000 children provided comprehensive data on clinical features, causes and effects of childhood head trauma seen in Accident & Emergency Departments.

The majority of children were examined by relatively inexperienced doctors at Senior House Officer Grade.

The Methods of Assessment were initially clinical. In the majority the subsequent investigation used was skull radiography. Doctors in all the units had complete freedom to request radiography in the form of skull xrays and used this investigation freely, though not as had been claimed routinely. There was, however, wide variation within the grade, with usage varying from less than 30% to 100%.

The matching of the request for skull radiography to the clinical features, provided an opportunity to discover factually whether, if guidelines were known to the doctors, they were implemented, whether the doctor did not know of the guidelines or chose to disregard them in respect of this investigation. Some doctors on interview were not aware of guidelines and used their own assessment of need. Many skull xrays were requested where the guidelines did not apply. Even those doctors, aware of guidelines, retained discretion to request skull radiography in the absence of the recommended criteria. The consequences of this approach resulted in a very poor yield of skull fractures from a very large number of skull films.

Evidence was produced which showed problems of interpretation of skull films, with both false positive 45, and false negative 15, interpretations of the 102 vault fractures confirmed by radiologist.

The diagnosis of a skull fracture, even erroneously, resulted in admission, because of the established unit protocols.

Instructions varied with regard to any history of loss of consciousness, but admission occurred in the majority.

The controversy with regard to guidelines for the management of the recently head injured child persists to the present time. This is not helpful to doctors in Accident & Emergency Medicine.

This Study has identified clinical symptoms, signs and causes and mechanism of head injury. It has demonstrated significant differences in the different age groups, and by sex. The risks of a skull fracture being present has been quantified by statistical analysis.

1. AGE

The highest incidence of head injury occurred in preschool children, 45%, with primary school children 39% and infants lowest at 8%.

Sex

Male children 66% are twice as likely to sustain a head injury as females, and the male dominance extended to infants 55%.

Skull Fracture

There were 102 confirmed vault fractures from the 5,993 children and nine clinical base of skull fractures. If skull fracture reflects the severity of impact, then the majority of head injuries in children in the Accident & Emergency departments were in the minor category.

Age/Fracture

The incidence of skull fracture was lowest in preschool children.
The vulnerability of the infant skull was confirmed with 25/102 skull fractures – 7.7% of both males and females.

Univarate Analysis

The probability of a child presenting with a head injury resulting in a skull fracture was found to be dependent on the age of the child. In particular infants (under one year) had substantially more fractures than expected.
When children under one year are compared directly with the older children they demonstrate a significantly higher risk, and have an odds ratio of 3.8 (CI=2.4,6.0). The odds for the older groups were 0.47, 0.86 and 1.79 respectively.
Children under one year are four(4) times as likely to have sustained a skull fracture than an older child.

Male Dominance

Significantly more than half the children presenting at the six centres were male.

Risk of Fracture by Sex

The probability of a child presenting with a head injury resulting in a skull fracture was found to be independent of sex.

The expected and observed numbers of skull fractures under a hypothesis of independence was independent of sex. This result was shown in both children under one year of age and in the older children.

Conclusions

The higher incidence of injury in male children is confirmed and includes infants and increases proportionately with age.

The probability of a child across all age groups having sustained a skull fracture was found to be independent of sex.

Risk of skull fracture was found to be dependent on the age of the child. Infants have substantially more fractures than expected.

The univarate analysis supplied takes no account of causes and mechanism of injury or of symptoms and physical signs.

Infants should be assessed with particular care. Children under one year are almost four times as likely to sustain a skull fracture, than the toddler and primary school group. There should be a liberal policy with regard to skull xray in infants. The circumstances of "the accident", and the radiological features should be evaluated to exclude abuse, in children under two years of age.

Skull fractures in infants are occasionally followed by complications, including a growing fracture, not seen in older children.

Depressed fracture may only be seen on skull xray when not previously suspected clinically, whether in the presence or absence of a scalp wound, and is an indication for skull xrays, with special views if required.

2.(a) CAUSE AND MECHANISM OF PAEDIATRIC HEAD INJURY

The most common cause of head injury proved to be falls. The number of falls as a percentage of all these causes occurred in the home 46%, play/sport 29% and school 11%. The location of the falls showed the home as the most common locus 54% and school the least common 11%.

Road Traffic Accidents accounted for 6% of all the causes, with child pedestrians at highest risk 2.8%, cyclists and occupants at similar risk 1.6%, and 1.7% respectively.

Fracture of the Skull and Causes of Injury

Falls produced the largest number of fractures, but were the commonest cause of injury, with a low risk of fracture.

The greatest risk of skull fracture occurred in Road Traffic Accidents with pedestrians and cyclists at greatest risk.

Non Accidental Injury was associated with 9.1% of fractures.

Scalp Features and the Cause of Injury were matched. Regardless of cause, deep short and long lacerations were associated with a high risk of skull fracture 4.6% and 21% respectively.

Univarate Analysis

The probability of a child presenting with a skull fracture was found to be dependent on the cause. In particular child pedestrians had substantially more fractures than expected.

Children involved in any Road Traffic Accident and compared to other subjects have a significantly higher risk of skull fracture with an odds ratio of 3.5. (CI=2.1,5.9).

Therefore a child sustaining a head injury as a consequence of a Road Traffic Accident is more than three(3) times as likely to have a skull fracture.

Children whose injury was identified as caused by non accidental injury/assault had a higher risk of skull fracture than other subjects, with an odds ratio of 5.4 (CI = 1.3, 23.5) and are five(5) times more likely to sustain a fracture.

Causes and Sex

The cause of injury was found to be dependent on the sex of the children. Males were more likely to be involved in a Road Traffic Accident or assault. The odds ratios were calculated (and are shown in detail in Section 2).

Conclusions

The probability of a child presenting with a skull fracture following a head injury was dependent on the cause of injury. Road Traffic Accident pedestrians had substantially more fractures than expected.

The cause of injury was found to be dependent on the sex of the child, male children being more likely to present, as a cyclist, injured in a road traffic accident, and after assault. This may reflect the activities in which males engaged, and a more aggressive approach.

Falls, the largest group, produced 73 skull fractures, the largest number at sport/play and the lowest at school.

Non-accidental injury, had the highest incidence of skull fracture for all causes.

The cause of injury has been shown to influence the doctors decision to request skull xrays. This is justified unless the criteria for CT scanning were met.

When the cause of injury is matched to the features of the scalp injury, it is shown that the cause of injury likely to produce a skull fracture are most commonly associated in children with scalp swelling and contusions and galeal lacerations.

2(b) MECHANISM OF INJURY

The sex of patients presenting with a head injury was found to be dependent on the mechanism of injury. Males were more likely to present having been struck with a blunt object than females, and females were more likely to present after a fall to a soft surface.

The odds ratios and confidence intervals for each mechanism were calculated and reported (Section 2).

Conclusions

The probability of a child presenting with a head injury resulting in a skull fracture was found to be dependent on the mechanism of injury

Children who have sustained their injury as a result of hard blunt impact have a higher risk of skull fracture than other mechanisms.

The influence of sex on the risk of skull fracture and the mechanism of injury shows males at greater risk of blunt trauma and assault.

Children who sustain head injury as a result of sharp impact injuries have a significantly lower risk of skull fracture, but penetrating injuries need to be excluded.

It was surprising that any fracture resulted from impacts on soft surfaces. This raises the question as to the accuracy of the history, and the possibility of abuse.

Sharp impact injuries have a low incidence of skull fracture. A child presenting with this mechanism is one fifth as likely to have a skull fracture as any other mechanism. When the mechanism of injury is a sharp contact, and this is related to the features of the scalp wound, ie. superficial laceration, and its location or site on the skull, e.g. frontal, and the risk of fracture calculated, a significant reduction in the requests for skull xrays could be achieved at minimal risk (see results – Scalp Wounds and Site of Injury (Section 4). This knowledge may allow a substantial reduction in skull xrays, with minimal risk to the patient, other factors considered.

3. COMA AND LOSS OF CONSCIOUSNESS

Loss of Consciousness and Coma is rare in the population of head injured children in the Accident & Emergency Departments 7%, reflecting the substantial numbers of minor injuries as identified by cerebral injury or impairment.

Loss of Consciousness and Skull Fracture

The predictive value of identifying a skull fracture and any history of loss of consciousness has been the source of much debate.

Univarate Analysis

This Study confirmed the probability of the head injured child sustaining a skull fracture was dependent on a history of loss of consciousness or amnesia, whatever the duration.

All categories of loss of consciousness had more fractures than expected.
When all children with a history of loss of consciousness or amnesia are considered as a group, and compared with other subjects, they demonstrate a significantly higher risk of skull fracture, and an odds ratio of 5.2 (CI = 3.3, 8.0).
The child with a history of loss of consciousness is five(5) times as likely to have a skull fracture, than the child without such an event.

The Sex of Patients

The sex of the child with a head injury was found to be independent of a history of impaired consciousness.
This fact would justify skull xrays in all children with any history of cerebral impairment, unless the criteria for immediate CT scanning were met.
Skull fracture increases the risk of intracranial injury, which loss of consciousness confirms.

Conclusions

Loss of consciousness is rare in the Accident and Emergency Department population of children who have sustained a head injury.
Any history of loss of consciousness of whatever length is associated with five (5) times the risk of skull fracture, than those who have not lost consciousness. The child in coma in the A&E Department, has 35 times the risk of skull fracture.
The sex of patients presenting with a head injury was found to be independent of a history of loss of consciousness.
This confirmation of risk would justify requesting skull xrays in these patients, unless they already fulfilled the criteria for CT scanning.
The request for skull xrays is justified in those children who have a Glasgow Coma Score of 15/15 in the A&E Department, but who are at risk of developing an intracranial haematoma. This would be particularly valuable in the child at risk of extradural haematoma. Some of these patients will present in the "lucid interval". They may have no clinical signs or symptoms, but fall into Teasdales(1990) category of higher risk, if a skull fracture is identified. This would expedite CT scanning before deterioration had occurred. The identification of a skull fracture has also been identified by both Lloyd et al(1997) and Quayle et al(1997) as

increasing the risk of non-neurosurgical intracranial injury. Knowledge of such injury will influence management.

4(a) SCALP INJURY

Identifiable scalp injury confirms trauma to the head.

The variation in the nature of scalp injury in the different age groups has been demonstrated.

The scalp feature and the risk of skull fracture has been calculated. Lacerations penetrating the scalp aponeurosis are associated with 4.6% and 21% of skull fractures.

Univarate Analysis

The nature of the scalp injury in infancy was significantly different to the older children.

The probability of a child presenting with a head injury resulting in a skull fracture was found to be dependent on the nature of the scalp feature.

Superficial lacerations had substantially lower numbers of skull fractures than expected. In fact a child with a superficial laceration was one fifth as likely to have a skull fracture than children with other scalp features.

Children with lacerations penetrating the scalp aponeurosis were at least five(5) times as likely to have a skull fracture.

The odds ratios for all scalp injuries have been calculated and reported (Section 4).

Sex

The sex of patients presenting with a head injury was found to be dependent on the nature of the scalp injury. Females were more likely to present with superficial lacerations, and males with scalp injury associated with skull fracture at different sites, some being more vulnerable to fracture, and this may vary by age.

Conclusions

Skull Fracture/Scalp Injury

Skull fracture was confirmed as being dependent on the nature of the scalp injury.

The nature of the scalp injury varies with age, infants being very different from older children.

The sex of the patient was found to be dependent on the nature of the scalp injury. In particular females were more likely to present with a superficial laceration.

Infants most commonly presented with scalp haematoma/abrasion contusion, in which there were 23 fractures. Superficial lacerations did not produce skull fractures at this age.

Children with galeal lacerations, a small group, had five (5) times the risk of having sustained a fracture, with the highest odds ratio being lacerations greater than 5 cms in length, with almost fifteen (15) times the risk of skull fracture.

Children with a superficial laceration are one fifth as likely to have a skull fracture as those with other scalp features.

In reaching guidelines for requesting skull xrays to detect a fracture it would be reasonable to withhold skull xrays in superficial lacerations, providing no other factors operated, particularly if the site also had a low risk, e.g. frontal, and the child a toddler.

In children with lacerations through the galea, skull xrays are indicated – including views for depressed fracture, because of the high risk, unless the criteria for immediate CT scanning are met.

Infants have a high risk of skull fracture, seen most commonly with scalp haematoma/contusion. There should be a liberal policy with regard to skull xrays in this group.

The value of skull xrays where scalp wounds are associated with a depressed fracture is not controversial.

They are also of value in detecting opaque foreign bodies in open wounds and may detect penetrating injury.The identification of the characteristic scalp wounds can influence management decisions.

4(b) SITE OF INJURY

The frontal site had the lowest incidence of fracture, whilst the parietal had the highest, 39/102 fractures. The vulnerability was confirmed across all age groups but was highest in infants, 35%.

Univarate Analysis

The probability of a child presenting with a head injury was dependent on the site of injury

The frontal and occipital sites had a substantially lower than expected rate of fracture. The child injured at the tempero parietal site was three(3) times more likely to sustain a fracture, only injury at more than one site carrying a greater risk. The odds ratios for the different sites have been calculated and reported (Section 4(b)).

Sex and Site of Injury

The sex of patients presenting with head injury was found to be dependent on the site, with females less likely than males to sustain tempero parietal injury, and more likely to present with no detectable site of injury.

Conclusions

More than 50% of the children presented with injury to the frontal site.

The frontal site produced the lowest yield of fractures.

Children presenting with a frontal injury had the lowest risk of fracture – odds ratio only 0.25 (CI 0.09,0.69).

Despite this, the group resulted in requests for skull xrays in 58%. Knowledge of this low risk might substantially reduce unnecessary radiography without endangering the patient.

When the frontal site and superficial lacerations are matched, the scalp injury is also shown to be associated with a very poor yield of fractures on skull radiography.

The vulnerability of the temperoparietal site to fracture, and the potential injury to underlying vascular structures justifies a liberal use of skull xrays, unless the criteria for immediate CT scanning are met.

The parietal site is affected commonly in infants, who should qualify for a liberal use of skull xrays.

Occipital fractures may be associated with less common clinical signs and symptoms. Posterior fossa haematoma may be detected by CT scanning, when the doctor is alerted by an occipital fracture. Delay may lead to sudden and unexpected complications.

Occipital fracture may be associated with contra-coup injuries of the frontal lobes again, presenting difficulties for the doctor in the assessment of the young patient.

5. HEADACHE AND VOMITING

If headache and vomiting is evidence of cerebral dysfunction only 24% of children were affected.

Headache and vomiting was more common in the older children 5 – 14 years.

The request for skull xray increased when these symptoms were present and were highest when both occurred in the same child.

The matching of the symptoms to skull fracture is reported. (Section 5)

Age influences the presence of these symptoms, as does the cause and mechanism of injury (Section 5).

Univarate Analysis

The probability of the child with a head injury, resulting in a skull fracture was dependent on headache, odds ratio 3.9. (CI = 2.5, 6.0)

Vomiting

The probability of a child presenting with a skull fracture was found to be dependent on a history of vomiting, odds ratio 3.2. (CI = 2.1, 4.8)

Headache and Vomiting

When headache and vomiting occur in the same child the odds ratio for skull fracture is 5.0, compared with the child with neither symptoms, odds ratio 0.20.
(CI = 3.0, 8.3).

Sex

The sex of patients presenting with head injury was found to be independent of headache.

The sex of patients was dependent on a history of vomiting.

Headache and vomiting with a history of loss of consciousness increases the odds ratio. Children with this combination of symptoms were more than nine(9) times as likely to have a skull fracture.

Conclusions

Headache increases the risk of skull fracture by four (4) times.

Vomiting increases the risk of skull fracture by three (3) times.

Headache and vomiting combined increases the risk of skull fracture by five (5) times.

The sex of patients with head injury was found to be independent of a history of headache.

The sex of patients with head injury was found to be dependent on a history of vomiting.

Headache and vomiting with head injury and any history of unconsciousness increased the risk of skull fracture nine (9) times, compared with children without these features.

6. DIAGNOSTIC IMAGING

There was a 64% request rate for skull radiography, clearly indicating that overall the requests were not made routinely, as claimed by many authors in the literature.

The largest numbers of children were seen by Senior House Officers and this grade of doctors had the highest rate of requests for skull xrays. There was however wide variation within the grade from as low as 30% to 100%. This may reflect inexperience or lack of knowledge of Guidelines for skull xrays.

It was of interest that Senior House Officer's in the Royal Aberdeen Hospital requested substantially fewer xrays, 45%, compared with 68% at Monklands mixed Accident & Emergency Unit.

There was a poor yield of fractures, 2.6% overall, from skull radiography.

102 skull vault fractures were confirmed by a Radiologist, nine base of skull fractures were diagnosed clinically, and one confirmed radiologically.

Casualty Officers made significant errors of interpretation. There were both false positive 45, and false negative 15 fractures diagnosed. The former led to admission, and the latter represented a 15% failure for the positive films at possible risk to the child.

Skull fractures were related to age with 7.7% occurring in infants, and in both males and females. The lowest incidence was in the preschool age group. Older males had almost double the rate of females of the same age, 12-14 years.

When the clinical features were examined in relation to xray requests, certain clinical features influenced requests. Details are shown in each Section.

Variations in requests and yields of fracture in more senior doctors compared with Senior House Officers, may have reflected experience, application of Guidelines or that they were involved with the more seriously injured.

This Study has identified features which carry a risk of skull fracture, which might both reduce the number of requests and increase the yield of fractures.

The realisation that in a six month appointment a Senior House Office might see two or three skull fractures, indicates a need for teaching and supervision.

False positive and false negative interpretation similarly showed the need for tuition in xray requests and interpretation.

A further survey of xray usage in Monklands Hospital after dissemination of

Guidelines showed an increase in xray requests from average 68% to 85%.

The reason why doctors request skull xrays is examined under Guidelines, (Section 14).

Multiple Logistic Regression

The data derived from this Study has identified risk factors for skull fracture. Skull fracture is associated with intracranial damage shown on CT scanning. It is also associated with an increased risk of intracranial haematoma.

It would be valuable to be able to combine risk factors in the head injured child and predict the overall risk of skull fracture. Patients at low risk need not be xrayed. Patients at high risk could have skull xrays. This would facilitate Triage for CT scanning, unless the criteria for that examination already existed.

THIS STUDY HAS ALLOWED THE GENERATION OF A MATHEMATICAL COMPUTERISED MODEL, TO BE APPLIED TO THE HEAD INJURED CHILD. THIS INCORPORATES THE VARIOUS CLINICAL FEATURES, TO DETERMINE THE LIKELIHOOD OF SKULL FRACTURE AND ITS PROBABILITY, (SECTION 6).

The benefits of knowing a skull fracture has been identified and is reported (Section 6).

It is proposed to make the model available in selected A&E departments treating head injured children. Audit may confirm its value and influence Guidelines for head injury management in childhood, in the future.

7. DISCHARGE/DISPOSAL

The proportion of the large number of children who attend in Accident & Emergency Departments, and who have indications for admission is relatively small, 12%.

The Study demonstrated different protocols for admission and the areas for inpatient care. The numbers requiring neurosurgical transfer were identified.

Sex

More female children were admitted. More males went to neurosurgery.

If admission reflects more severe injury, the causes and mechanism are relevant, with Road Traffic Accident trauma resulting in the highest rates of neurosurgical transfer.

Assaults/Non-accidental Injury

These resulted in a 50% admission rate, with non-accidental injury having the highest mortality and morbidity.

History of Loss of Consciousness

92% with no suspicion of loss of consciousness were discharged.

There were different policies between the units in the Study, if there was even a brief loss of consciousness.

Skull Fracture

Recent skull fracture resulted in admission in all hospitals. Fracture Triage in the Accident & Emergency Department for CT scanning might reduce the request for admission, with financial saving.

Conclusions

The data confirms that large numbers of children, 5265/5993 – 88% went home. Many sustained minor trauma to the scalp only.

Within the remaining 12% were the minor injuries, where some features caused sufficient concern to result in admission for observation. This is the group of patients, who appearing satisfactory, were considered at risk of developing complications, or had symptoms.

In childhood the vomiting patient requires observation and symptomatic relief. The possibility of childhood concussion is raised. Deterioration not due to a mass lesion may be due to the onset of cerebral swelling, for which to date, there seem to be no reliable predictors. The moderately injured will require admission for definitive treatment for the head and possibly other injuries.

Severe injury, only 3% of the total will require the full resuscitation skills of a multi-disciplinary team, and may subsequently face the hazard of inter hospital transfer.

The cause, mechanisms and features of severe injury are shown in the data tables. Appendix 7(a), whilst the care of the moderately or severely injured child is presented in Appendix 7(b).

The decision to transfer a child to a distant Neurosurgical Unit is one of the most difficult a doctor in the A & E Department has to make. It is certainly a situation which puts a heavy responsibility on to the medical officer Unfortunately too often in the past it has been made on the principle of "scoop and run", At the opposite end of the spectrum is delay, which has resulted in avoidable mortality and morbidity reported in past decades, and often in observation wards.

There are inevitably areas in pre-hospital care which have features and requirements in common with interhospital transfer, and with resuscitation within the A & E Department. Having made the decision, action must follow a strict and disciplined pattern. Full resuscitation must have been achieved, based on the principles outlined. There must be adequate assessment of both the neurological condition, and other injuries. A provisional diagnosis should be made, and in the absence of urgency, investigations undertaken. In particular the status of the cervical spine should be established. Skull xrays are normally indicated, unless the criteria for urgent scanning are met. Continuous monitoring ensures that the patient is stable and fully oxygenated. CT of cervical spine will reveal fractures not seen on xray.

Hypovolaemia should be treated by intravenous infusions, and the control of blood loss. Should the latter not have been achieved, consideration should be given to the wisdom of transferring the patient and senior surgical advice is essential. Fractures not requiring immediate treatment should be effectively splinted, and pain relief should be administered. Specialised Transfer Ambulances are ideal with senior experienced medical and nursing staff escorts.

Monklands Accident & Emergency Department has had for 18 years, a dedicated self sufficient Life Support Trolley designed by the Author. This allows monitoring and treatment during resuscitation and intrahospital activities.

Transfer is effected by placing the Trolley in a dedicated fully equipped Intensive Care Ambulance. Apart from the clear benefits for the patient, there was a dramatic improvement in the knowledge and practice of junior doctors. They had previously been unaware of the principles of care in transit, and the concepts applicable. Unless Trauma Centres are widely established in the U.K., the role of the Emergency Physician in resuscitation and transfer is a challenge, which must be addressed in the interest of head injury survival, and improved outcome, in conjunction with Neurosurgical colleagues, in the foreseeable future.

8. INTRACRANIAL HAEMATOMA

The incidence of intracranial haematoma in patients under 15 years of age is low - 0.25 % - 1:400 in head injured attenders.

Intracranial haematomas in the child were matched to age, sex, clinical features, causes and mechanism and the results were recorded (Section 8).

Nine of the 15 haematomas were associated with a skull fracture.

The majority presented within two hours of injury, identifying the locus of potential delay in the hospital, rather than the pre-hospital setting.

The risk is increased 80 times by a skull fracture, except in infants where the odds ratio is 1.00.

The risk is increased five(5) times in the presence of a history of loss of consciousness of any duration, including the lucid interval.

In the A&E Study skull fracture secondary to blunt trauma was the feature most commonly identified with an intracranial haematoma.

The interval from injury to arrival in hospital, in cases where an intracranial haematoma was subsequently identified, showed that the majority presented in less than two hours and before neurological deterioration had occurred.

Univarate Analysis

The probability of a child with a head injury resulting in a haematoma was found to be dependent on the presence of a skull fracture – the odds ratio was 86 (CI=30.05, 246.10).

This indicates a child in the Accident & Emergency Department presenting with a haematoma is 86 times more likely to have a skull fracture, than the child who does not have such a fracture.

There is a marked difference in children under the age of one year. This group does not have an increased risk of haematoma when a skull fracture is detected. The odds ratio is 1.00 (CI=0.99, 1.00).

This is of practical importance because this group present practical problems of CT scanning, when conscious and unable to cooperate. Observation may be the best option, rather than scanning, requiring sedation or anaesthesia.

When a history of loss of consciousness has occurred, including the lucid interval there is a probability of a haematoma occurring, odds ratio 5.2. (CI=3.3,8.0)

Conclusions

Casualty Officers are unlikely to have first hand experience of a haematoma in a six month appointment. It is essential therefore that guidelines issued to doctors address this problem, so that the haematoma is identified before deterioration is allowed to occur. The numbers are small, but suggest that the identification of a skull fracture leading to CT scanning may be the emergency doctor's first indication of risk.

The child without skull fracture may well have other features which mandate immediate CT scanning, without requests for skull radiology.

Although the risk of haematoma in infants was shown to be statistically low, special note has to be taken of the vulnerability of children under the age of two years to non accidental injury.

The detection of a skull fracture in Teasdale's(1990) review sought to ensure early CT scanning. This presents practical problems in the young child if sedation or anaesthesia are necessary to obtain quality scans. The reduced risks in infants is of practical significance, and the alternative of admission for observation may be acceptable, providing the staff caring for such children are fully trained and experienced in neurological assessment, and that the doctor is alerted by the most subtle changes in the child's cerebral status.

These facts would allow more selective use of skull radiography with conservation of resources and reduced radiation for the child. The association between skull fracture and intracranial injury has been reported by others, based on more extensive availability of CT scanning in recent years.

The identification of a skull fracture, though not necessarily its absence, I submit is valuable in the ongoing assessment and management of the child. Skull radiography should be used to triage children for CT scanning, if the criteria for that examination are not already met. This does however present some logistical problems and the detection of a skull fracture in a neurologically normal child may be best used as an indication for admission for observation.

There are additional factors which should be applied to the requests in the youngest children, which have been identified. There should be a liberal use of skull xrays in infants and children at risk of non accidental injury because of the serious implications.

8. EPILEPSY - SEIZURES

A seizure was recorded in 1% of children who had sustained head trauma. 18 were post traumatic, seven were associated with pyrexia and secondary injury to the head. The observation of a seizure is vital to the care of the child. Rapid control is mandatory, and the identification of its cause essential.

Conclusions

Seizures were rare in the A&E Departments accounting for only 1% of the attenders. Epilepsy complicating head trauma represents an acute crisis for the emergency doctor. Whatever its cause it requires urgent and efficient intervention and control.
A seizure may:
Produce secondary insult following minor trauma, with a resulting disability far in excess of the original primary injury.
Indicate intracranial complications requiring skull xrays/CT scanning and surgical intervention. Seizure activity must be controlled both centrally and peripherally prior to transport, and may require the skills of an anaesthetist/paediatrician.
Febrile convulsions associated with head trauma require a reduction of temperature and treatment for the underlying pathology.
A seizure requires further subsequent investigation if it is the first manifestation of non-traumatic symptomatic or idiopathic seizures.
The risks of long term epilepsy should not be discussed in the emergency situation, because of the complex and multiple factors which operate in childhood from different causes and in different ages.

10. OUTCOME

The Accident & Emergency Department treats the largest number of minor head injuries and the smallest number with severe injury.

The isolated head injury, and that associated with multiple trauma presents different challenges to the medical staff. Resuscitation, prevention of secondary insults to the brain, the challenges of on site care and supervision in transit to specialist units, influence the outcome for cerebral injury and require particular skills.

Conclusions

The figures confirm that Casualty Medical Officers in a six month appointment will have limited opportunity to see and participate in the management of moderate and severe head injury, and even less where multiple injuries are present in the head injured child.

Senior experienced Accident & Emergency staff supported, where possible by a multidisciplinary team, including a paediatrician, and anaesthetist, are essential to meet the infrequent demand, which requires skill, knowledge and experience of major rescucitation and cerebral protection.

11. ATTENDANCE PATTERNS

The attendance patterns of children with Accident & Emergency Departments are affected by a variety of factors.

This Study showed that paediatric care following head injury was influenced by the resources available.

This has particular influence in the UK for out of hours attendances in 24 hour departments, whose resources did not meet demands made by children.

Conclusions

The attendance patterns in six UK Accident & Emergency Departments had a number of factors in common. The majority of children came short distances in urban settings.

In major departments resources would be expected to be comparable throughout 24 hours.

The attendance of more that half the children outside "social hours" was a cause for concern. Dedicated staff were not always available either clinically or technically.
Delays to medical care did not occur prior to A&E arrival.
CT scanning was not available out of hours in five of the units.
The message is clear – if departments claim to provide a head injury service to children the resources must be available to meet demands whatever the time, day or month of injury.

12. THE CARE OF CHILDREN IN ACCIDENT & EMERGENCY DEPARTMENTS

The section of the Paediatric Study which examined the Care of Children in Accident & Emergency Departments did not set out to examine its influence on outcome.
It was intended to identify deficiences reported 30 years ago and to see, what, if any advances had been made in the intervening period. A separate audit would be required to assess quality control.
The paediatric hospitals met many of the recommendations. The mixed departments did not. The findings of this Study have been endorsed by the Report of the Working Party of the Royal College of Paediatrics and Child Health (1999).

Conclusions

It was sobering to have to admit that Jackson's criticisms, and the ongoing failure to meet recommendations for the Care of Children in Hospital were applicable in Monklands District General Hospital. Whilst inevitably the conditions for the child with minor or moderate head injury warranted criticism and identified the need for improvement in the A&E Department and in the observation ward, the Study did not identify such inadequacies in resuscitation or transfer. The question however was raised as to whether children should, in the interests of quality of care, all be treated in dedicated paediatric units? If they are not, clearly there are major issues still to be addressed since the Court Report almost three decades ago, set standards for paediatric care in hospital. Overall care of children in adult departments is still far from ideal in terms of resources.

Whilst some improvements have been noted the recent Report of a Multidisciplinary Working Group, Accident and Emergency Services for Children(1999) convened by the Royal College of Paediatrics and Child Health, confirms that the facilities and resources available do not meet the standards previously set and are appointing an Intercollegiate Advisory Group to oversee their recommendations in the future.

The availability of specialised courses in Paediatric Life Support should bring benefits, as more doctors gain access to instruction in practical procedures, and expand their knowledge of management of the seriously ill child.

13. CHILDREN ARE DIFFERENT TO ADULTS

In addition to this Author's publication, Brookes et al(1990), this Study confirmed the variations between children and adults and children of different ages.

Conclusions

Children who sustain head trauma and attend A&E Departments are different to adults, but also from children of different ages.

They differ in their causes and mechanism of injury.

The scalp features often indicate less serious injury, with smaller numbers of children manifesting cerebral trauma.

The scalp injury and results of xrays are different in the varying age groups.

Children lose consciousness less frequently than adults.

Children differ in their tendency to vomit after head trauma by age group and sex and compared with adults.

Headache may be less readily identified.

Fewer children attending A&E Departments are admitted to hospital than adults.

Children vary in their risk of skull fracture in different age groups and cannot be directly compared to adults.

Children vary by age in their risk of skull fracture.

Children less frequently develop intracranial haematoma than adults, but risk varies by age group.

The relationship of intracranial haematoma and skull fracture indicates a lower risk in children, particularly infants.

Children develop complications of skull fracture not seen in adults.

Children develop complications unique to childhood.

The differences in admitted children and admitted adults were not examined in this A&E Study.

There was a more confident approach in the Paediatric A&E Department at Aberdeen, where all the doctors ongoing experience was with children. By contrast at Monklands Hospital, children were only a small part of the spectrum of head injury decisions, and the demands made upon doctors were for more wide ranging.

14. <u>GUIDELINES</u>

Guidelines for the management of recent head injury in adults have existed for several years. They have been issued in relation to diagnostic imaging by Radiologists. Clinicians have formulated Guidelines which have been endorsed by the Department of Health.

Yet this Study has shown that some doctors were not aware of guidelines, others did not always follow them, and retained the right to act in a one to one situation with their patient.

The Study has identified a value from guidance, which supports the doctors, who have confidence in them. By facilitating a disciplined approach the quality of care afforded may be improved, whilst reducing radiation and conserving resources.

The identification of risk factors for skull fracture in this Study will facilitate better selection for diagnostic imaging.

The author has formulated Guidelines accordingly – Section 14.

THE FORMULATION OF A MATHEMATICAL MODEL TO UTILISE THE RESULTS OF LOGISTIC REGRESSION ANALYSIS, AND THE APPLICATION OF THE CONCLUSIONS TO CHILDREN, FOLLOWING HEAD TRAUMA SHOULD REDUCE UNNECESSARY RADIOGRAPHY, AND ALERT THE CLINICIAN MUCH EARLIER TO THE POTENTIAL FOR INTRACRANIAL COMPLICATIONS.

E. REVIEW OF THE LITERATURE

REVIEW OF LITERATURE

1. Age/Sex
2. Causes/Mechanisms of Injury
3. Loss of Consciousness
4. Scalp/Site of Injury
5. Headache/Vomiting
6. Diagnostic Imaging
7. Disposal
8. Intracranial Haematoma
9. Epilepsy
10. Outcome
11. Attendance Patterns
12. Care of Children in Accident and Emergency Departments
13. Children are Different
14. Guidelines

1. Development, Age and Sex

Children are not miniature adults, a fact well recognised across the whole spectrum of medical care. They are not, within the definition of paediatric used within this Study, a homogenous group either. The infant and child under two years, is anatomically different, not only from adults, but from children in the pre-school and school years. There are substantial differences in the level of dependence on parents and carers. Infants have limited independent mobility. Toddlers are developing skills, which progressively increase their mobility, without adequate control and coordination or awareness of danger. They also have a head disproportionate to the size of the body, which results in a propensity to fall or topple over. As development, physical and intellectual, proceeds they become more inquisitive, exploring the potentially hostile environment. They are exposed to new structural and physical dangers, as they leave the domestic, for the outside world. The acquisition of physical agility, participation in group sporting and leisure activities, may expose the male and more aggressive child to new hazards, particularly in adolescence. Mechanisation, first at play and later on exposure to motor vehicles increases the potential for injury, from a wide range of causes and mechanisms. In school, restraint and discipline may modify risk. Changing social patterns, have put children at risk of violence, both within the home and in the community.

<u>The Anatomy of Head Trauma</u>

There are marked differences in the anatomical features of the child at various ages, and matching unique characteristics of the immature central nervous system. Children under the age of two years demonstrate the most marked differences from their older counterparts. One of the most striking is the disproportionate size of the skull in infancy and early childhood compared with the older child and adult. The brain at birth comprises 15% of the body weight, compared with 3% in the adult. The growth is rapid, reaching 75% in the second year and 90% by the age of six years(Kreil, Krach and Danser 1989)

The foetus is provided with a skull with flexibility to enable it to pass through the birth canal. The base of the skull is rigid, the vault a series of hinged plates with open fontanelles. These features, together with the thin vault bones and pliability allow the dissipation of low velocity force.

The Development of the Central Nervous System

The development of the brain begins in utero. Cortical neurones are formed between 10 and 25 weeks gestation, with maximal development round the end of the first trimester. Once developed there is no ability to form new elements, except in the cerebellum. Dendritic formation and differentiation continues to six years of age. Myelination completes the process, commencing before birth in the cranial nerves and spinal roots, and continues into late childhood. The process of myelination correlates with function. The absence of myelination in some of the brain tissues is probably associated with increased susceptibility to shearing forces, i.e. to more severe injury.

The differences between children and adults in their response to injury are related to the concept of plasticity. This is an ability of the child to sustain injury, and to recover better than the older child or adult with a comparable injury. This is a feature particularly of the speech area following injury to the left hemisphere in pre-school children(Mitchell et al 1994). One of the differences in evaluating the phenomena when injury is imposed on the immature brain, is not only the effect of that injury, but absence of a base line of function, and the added problem of arresting the maturation process.

The water content of the immature brain is greatest in infancy, 87% in the cortex and 89% in the white matter. It is progressively reduced in the first decade and gradually assumes an adult norm of 83% and 69% respectively towards the end of the second decade The changes in the child's brain and its progressive development is well documented. Much less is known about how the pathological processes influence the sequential development, and the orderly or possibly disorderly progression following injury.

Vascular patterns related to nourishment of the infant brain are believed to parallel functional development. The response to hypoxia or hypercarbia has been less well documented, than in adults, but may be better tolerated by the immature brain. By contrast, high levels of oxygen can cause cerebral retardation in infancy, particularly in the premature infant. The factors controlling vascular autoregulation and their comparison with adults is not known.

Intracranial Pressure

Cerebral perfusion pressure is the difference between the mean arterial pressure and the intracranial pressure. As mean arterial pressure in children is lower than in adults, CPP may barely reach the 50 mmol of mercury essential to adult perfusion. It is not known what effects falling below this level may have on the immature brain.

Evolution has provided the brain with a rigid protective casing, which dissipates some of the energy applied by localised low velocity forces. The brain, surrounded in adults, by 1,200-1,500mls of fluid was in the distant past well protected. Technological progress has exceeded evolutionary development. As a consequence the human brain is now subject to rapid movement following impact on stationary objects, or surfaces. The brain suspended within its fluid cushion, by membranes and blood vessels, is vulnerable to the forces applied. The protective structure paradoxically, contributes to patterns of injury seen, when the pliant brain is driven against the rigid buttresses most commonly affecting the frontal and temporal lobes which become contused(Brink et al 1980; Kumar et al 1991). Membranes and vascular structures suspend the brain in its cerebro spinal fluid. Vascular channels pass from the brain's pial surface through the subdural space to the dura. Excessive movement results in tearing of the cortical veins at their insertion into the membrane, which is fixed, with haemorrhage into the subdural space resulting in a subdural haematoma. The dura, effectively the periosteum of the inner surface of the skull, is held firmly to the bony surface. Arterial blood vessels are held firmly in place by the dural membrane. Localised trauma to the skull resulting in a fracture can sever blood vessels with resulting arterial bleeding into the extradural space. In the pliable skull of the younger child a fracture may not be necessary to produce this arterial injury. The flexible skull is deformed, tearing the blood vessels but springing back to its original position. In addition the intracranial space is divided into a system of compartments by the central falx cerebri and the tentorial membrane. In normal activity these structures provide a degree of stability preventing mass displacement. The disadvantage is that the rigidity of the membranes may contribute to injury of the brain, and expanding mass lesions with associated raised intracranial pressure can result in disastrous compression and uncal herniation. A vicious circle is set in motion with obstruction to the cerebrospinal fluid drainage and to effective blood flow. The results are hypoxia and infarction of areas of the brain. The skull may protect underlying structures from penetrating injury, of low velocity. The thinner bony areas are more vulnerable to penetration by sharp objects. High velocity penetration and destruction is a feature of the effect of firearms.

In childhood developmental factors linked to age, need to be taken into account. Development of the skull and the central nervous system develops in-utero. Flexibility is retained to facilitate birth. In the infant and young child the head is disproportionately large in relation to the body. The skull in early life is a series of hinged plates, held together by fibrous cranial sutures, which act as joints. Between these the two fontanelles remain open to the end of the second year of life closing gradually. A degree of mobility is available when force is applied. A subtle compromise between rigidity and mobility was noted by Peacock et al(1986).

The importance of a knowledge of the anatomy and development of the skull and its contents was emphasised by Copolla(1973). It also has relevance to the interpretation of skull xrays, when features at variance with the fully developed adult skull may predispose to the misinterpretation of fractures.

By the age of two years the brain has achieved 75% of adult weight by 5-6 years 90% and by adolescence 92%. The skull, now with its closed fontanelles has reduced flexibility further reduced as the sutures fuse. It still provides protection against low velocity impact, the inner compartments restraining excessive movement. Strong forces applied can result in injuries to the brain which are a direct consequence of the anatomical features. In the infant and young child the inner surfaces, particularly of the vault, are smooth. As development proceeds, the base of the skull has rigid and irregular surfaces against which the lobes of the brain impact with resulting injury. The rigidity of the closed box effect is disadvantageous. Trauma can result in a substantial rise in intracranial pressure and contents. Lethal effects result from an expanding mass lesion. Vascular channels are compromised, and the brain tissue is compressed. High velocity forces result in the brain impinging on rigid structures, lacerating brain tissue and blood vessels. Ultimately displacement and herniation occurs impeding the flow of cerbrospinal fluid, and adding to the pressure inside the skull.

The anatomical features of the cranium can contribute to the primary irreversible injury, which occurs at the moment of insult. Secondary volume expansion, which follows, cannot be effectively compensated within a closed system. Elevation of intracranial pressure results. It is this interaction of many features which contributes to raised intracranial pressure. Its development may be an inevitable response to the primary trauma. More important in the Accident & Emergency Department are the effects of secondary insult, which may be avoidable.

The initial and timely management decisions by emergency physicians are crucial to their avoidance and amelioration. Those injuries serious from the outset warrant aggressive and urgent interventions, those at risk demand constant attention and vigilance and preventive measures. Once established the resources and skills of neurosurgery and intensive care are required. Even so the scene may be set for a disastrous outcome. The importance of prevention of the secondary insult cannot be overemphasised.

Age and Sex

Trauma is a major killer of children and head injury accounts for at least 40% of the deaths(Haller 1983). Brain injury in the United States of America varies from 185 - 220 per 100,000 of population per year. It results in 100,000 paediatric hospital admissions and 500,000 emergency attendances. 25,000 children die annually from cerebral trauma. Male children are much more likely to sustain head trauma and their injuries are more likely to be severe or fatal, a fact reflected in the many publications on outcome from severe head trauma. Overall, twice as many male children sustain head trauma as females. Age too influences outcome for similar degrees of trauma(Annegers, 1983).

Information on the incidence of head trauma, and the type of cerebral injury, which results, has been derived from epidemiological studies. The data is required for planning and utilisation of health care resources in relation to defined populations(Jennett 1981). These include facilities for admission, including Neurosurgery and Intensive Care. There are also implications for Emergency Services both pre-hospital, transportation, emergency room and for investigative resources.

Detailed analysis provides information on the characteristics of the patient, causes and mechanisms of the accident, and the resulting cerebral injury and outcome. One of the difficulties encountered with epidemiological surveys is the lack of precise definitions. This applies to the age limit applied to the paediatric group, which has been extended from birth to as much as 21 years. Categories of injury, interchange of definitions, for example, cause and mechanism, and gradation of injury have made comparisons difficult between individual reports. In children there has until fairly recently been infrequent sub division into age groups, even when 15 years has been set as the upper limit, despite the obvious variables within paediatric head trauma from infancy to adolescence.

It is possible that minor cases of head trauma are not reported. They may, particularly in rural areas, if the injury is considered minor, report to a family doctor. This rarely occurs in urban areas. The anxiety generated by head injury is likely to result in referral for assessment, or skull xray and even if primary care statistics were kept, the patient is likely to be counted a second time in the Accident & Emergency Department numbers. The role of the Accident & Emergency Department in the recovery of data is vital.

Epidemiological studies, mainly from North America have produced data on adults (Klonoff and Thomson 1969) and by Klonoff and Robinson(1967) in a pilot study on children Klonoff(1967) undertook an analysis of 298 head injured children and examined a total of 28 features. The children were divided into groups by age and by the hospital level in which they received their medical care. There was an emergency group. Those who were admitted to hospital were also analysed, and there was a matched control group. The results confirmed the dominance of males. The data was comprehensive, and led the author to number of conclusions. Boys were more vulnerable to head trauma than girls by a ratio of 12:7. Very young children from infancy to four years were susceptible to head trauma, consistent with previous reports of Burkinshaw (1960) and Partington(1960) The study had addressed the question of accident proneness previously reported. The conclusion was that a propensity to injury could only be related to the male sex. Repetitive accidents were also examined. A history of previous head injury was more common in boys, but did not reach significance. The greater frequency of previous head trauma in older age groups, particularly the male could not be defined as accident proneness because increasing age offered more opportunities for injury. No conclusions regarding accident proneness in male children could be reached. Klonoff and Robison(1967) found that other factors relating to a predisposition did not reach significance, when compared with the controls. Environmental factors influence the incidence of trauma, congested housing, low income, marital instability and low occupational status. The authors concluded that at the time of the accident the nature and extent of parental or adult supervision was important and was related to the age, but not to the sex of the child.

Klauber et al(1986) conducted a telephone survey on 1,213 non-fatal childhood injuries, covering poisoning, burns and head injury. The age limit was set at 14 years. 4.2% proved to have sustained head trauma. The mean age was 5.5 years, and male dominance was greatest in the head injured group. 2:1. Klauber(1986) said that the results of their survey were consistent, with almost every other study of childhood injuries in which boys dominated. The particular excess in head trauma of males, compared with the poisonings and burns was noted. Klauber(1986) comments that from infancy onwards, children have sufficient mobility to get into trouble but not enough sense to stay out of it, echoing similar views expressed by Burkinshaw(1960). The continuing rise in the proportion of head injuries with increasing age was considered to reflect behavioural and sex differences, and participation in dangerous activities. Social characteristics including working parents, and differing attitudes within social status revealed no significant causal relationships.

Kraus et al(1986) studied 709 children, 70% with apparently minor head injury under the age of 15 years in San Diego County. Males dominated in all age groups, and the proportion of males increased progressively to age 15 years. There were age and sex differences for different causes. Males 1.7:1 for falls at all ages, in the under five year olds recreational activities produced a male ratio of 2.7:1. As age advanced male dominance increased. Non motor vehicle bicycle accidents were the most common male recreational activity producing head injury over five years of age. The male/female ratios for motor vehicle accidents was 2.1:1 and varied little with age, two thirds of those affected were unprotected road users, pedestrians or cyclists. This represents a sharp contrast to adults when two thirds were occupants and only one third unprotected road users.

Assault and fire arm cases were 4% of the total in this study. Fifty seven percent of children injured in this way were female, though they accounted for only 37% of the total childhood brain injuries. 30% of the childhood assault and firearm cases were children under one year, 30% were 1-4 years old, 10% were 5-9 years of age and 30% 10-14 years, at variance with the age distribution in the population. Kraus et al(1986) offered no explanation for these remarkable statistics.

If it is assumed that all significant cerebral trauma is likely to be brought or seek emergency medical attention in an Accident Unit, information derived from the emergency record should be able to provide extensive data on the incidence and characteristics of head injury.

One of the problems which has caused criticism to date is the dearth of information often recorded on the emergency record card. This problem is being addressed in many Units with a special interest. The use of a formal preprinted record(Marsden 1987) acts as an "aide memoire" and ensures that information often acquired is actually recorded. It is perhaps for this reason that prospective studies are of much greater value than retrospective record review. Experience with research projects confirms that considerable information can be recorded by the simple method of providing a structured record.

Field(1976) in presenting his monograph on the epidemiology of head trauma had commented on the lack of information produced by Accident & Emergency Departments. This deficiency was soon met by the Scottish Head Injury Management Study(Strang, MacMillan and Jennet 1978) by reports by Swann, MacMillan and Strang(1980) and Gorman(1985). The Monklands Study was undertaken in 1984 by M T Brookes and examined the characteristics of 3,971 patients, 1,720 of whom were children. The data so collected has been incorporated in publications by Ballantyne et al(1986), Thillainayagan et al(1987), Teasdale et al(1990), and Brookes et al (1990).

In the USA Rivara et al(1982) examined the records of 197,561 children under 18 years of age collected by the National Electronic Injury Surveillance System NEISS. This was based on a representative sample of 130 hospital emergency rooms in the United States. The data was abstracted on a daily basis from the emergency room records and subsequently coded. Motor vehicle accident trauma was excluded. Head trauma accounted for 11% of these emergency room visits.

Rivara(1982) found that children under seven years of age had the highest rates of head injury with a peak at 1-2 years. For infants under one years, 30% of the injuries involved the head, making it the most common non-motor vehicle injury in this age group. Head injuries make up a large proportion, 19% of the one and two year olds and three to six year olds. School children and adolescents with head injury make up 9% and 6% respectively.

Rivara(1982) reported a striking male dominence for head injury by one year of age and 2.7 times the head injury rate in females of school age. Infants had the highest rate of skull fracture, 6%.

He related the risks and type of injury to factors including development. Children under school age have the highest risk of head trauma and have the highest usage of emergency room facilities. The proportion of head trauma was highest in infants, attributed to the large heads and high centre of gravity. Most of the injuries in the preschool group were minor, but were considered preventable.

Head injuries in school children and adolescents tend to be more serious. Males had twice as many injuries as females in this group. There was a higher rate of concussion in these adolescents, indicative of more severe impact forces. The role of sport, both competitive and informal was significant. Injuries in these categories might be prevented by helmets, a topic which Rivara(1982) discussed further.

This study showed that, having excluded motor vehicle accidents, the head injury sustained was in the majority relatively minor. Rivara commented however on the sheer volume of the estimated 500,000 emergency head injury attenders each year. This represented an enormous health care, social and financial burden, which was amenable to prevention.

MacKellar(1989) working at the Princess Margaret Hospital, Perth, Australia, undertook a survey of 7,967 children attending in the Accident & Emergency Department. 3,187 or 40% had sustained a head injury. The cases were divided into minor, 80.7%, moderate admitted for observation 17%, and severe 2.2%. The sex was 64%, male 36% female. The age distribution was 0-4 year 54%, 5-9 years 30% and 10-14 years 16%.

MacKellar's Study showed recurring problems relating to head trauma, which he suggests should be amenable to preventive measures.

In 1985 Brookes undertook a prospective Study over a nine month period in the Accident & Emergency Department at Monklands District General Hospital subsequently known as the Monklands 1 Study. 3,971 patients were identified. After exclusion of facial injuries 1,720 children fulfilled the criteria for analysis. There was a clear definition of both head injury and paediatric status - age under 15 years.

The characteristics of these children were subsequently (1990) compared with children attending in the emergency room of the Hermann Hospital, Houston, Texas and also with data from the previous Scottish Studies. The results of the comparison with respect to age and sex is shown.
(With permission of Jennett unpublished) 1990.

TABLE A

	%	Age	Group		%	Male
	Hermann	Scot	Monk.	Hermann	Scot	Monk.
N	643	2118	1720			
< 5 years	50	45	46	57	63	58
5-11 years	37	41	41	61	72	70
12-14 years	13	14	13	59	77	78
All	-	-	-	59	68	65

When examined by sex for severity of injury 86% of both male and females at Hermann were in the minor head injury category. When assessed, by the Glasgow Coma Score more children at Hermann were considered to have sustained brain damage as a result of which the discharge rate was lower 87% in Hermann, 93% in Scotland and 93% at Monklands.
An extensive analysis of the epidemiology of head injury was undertaken by Berney(1994) and his colleagues. He commented that Raimondi had regretted that little attention had been given in the literature to the effects of age on head trauma. A study was undertaken on 1,812 children under 15 years of age, who had attended or been admitted to the children's hospital in Geneva.
Berney(1994) examined the effects of age and sex on the epidemiology of head injury. 1,812 children were subdivided by severity of injury, 1,503 were categorised as benign and 309 as severe. They were further subdivided into groups by age and the infants separated into a subgroup. The sex differences, with males dominating was observed in all ages including infancy. The youngest ages had the highest incidence of head injury. The number increased progressively, with males dominating, particularly into the 1-3 year old group and the 9-15 year olds.
When age is related to cause, falls from a low height occurred most commonly in babies and young children of each sex.
When the injuries were related to sex these authors reported that girls were more commonly injured as car occupants and in falls from horses. They also developed

extradural haematomas more frequently as a consequence of falls, motor vehicle accidents, and miscellaneous events. It was suggested that girls fell more awkwardly and were less able to protect themselves from injury. In this study girls were more likely to lose consciousness, to be in coma and to sustain fractures. The authors concluded the girls sustained as severe injury as boys. This is not compatible with reports of other studies. The authors admitted to imperfection in the methods of their study and to approximations rather than factual calculations!

In discussing the range of causes and circumstances in which children sustained injury, inadequate adult supervision or control was mentioned, as it was in MacKellar's paper(1989).

Mitchell(1994) more recently reported on minor head injury in 401 children - males dominated.

2.(a) Causes of Injury

2. (a)(1) Falls

A child's psychomotor development does not occur at a matched pace. The child is able physically to carry out tasks, and to increase his or her mobility, well in advance of the development of awareness of hazards. Injuries in the pre-school years are common. The toddler is top heavy anatomically, and has less than perfect muscular co-ordination, hence tumbles and falls within his or her own height are common. As the child develops more mobility, and independent activity is achieved, adventurous activities, climbing trees and various structures introduce the potential for falls from a height. Unsupervised children in urban high rise housing are at particular risk(Bergner, Mayer and Harris 1971).

The factors which determine the severity of injury in falls are velocity or magnitude of the force applied, the distribution of the force, the nature of the contact surface and the duration of impact time(Gupta, Chandra and Dogra 1982). The height from which a child falls determines the speed; the greater the height the greater the speed of fall. This is not necessarily directly related to the severity of the injury and is not related to the weight of the child(Snyder 1963). The position of the body on impact determines the site and severity of the injury; a fall head first will clearly produces a greater degree of injury to the head, than when the body impacts and the head strikes secondarily.

The surface on which the head impacts influences the injury sustained. Cummins and Potter(1970) have contrasted the effects on skull fracture of falling on grass or falling on concrete, from a comparable height. The latter causes more than twice as many skull fractures as the former.

Acceleration/deceleration injury is affected by the length of time the impact force is applied. Although children, less aware of danger, may be more flexible, and land in falling in a relaxed state, the injury sustained is not necessarily less(Barlow et al 1983). There is an effect of age, in that the very young are more vulnerable to injury in falls from a height, particularly infants(Reynolds, Balsano and Reynolds 1971).

One of the problems in the infant who presents with cerebral trauma is whether the injury was accidental or abuse. Falls are frequent in children and often cited as the cause for the abused child's injury. There is increasing evidence that short falls never or rarely cause a serious injury(Reiber 1993, Chadwick et al 1991, Duhaime et al 1992). The child's height has been used as a yardstick for risk. Children falling less than 1.2 metres were never fatally injured according to Chadwick(1991) in a review of 317 children. Duhaime et al(1992) found that when it was claimed that short falls resulted in severe cerebral injury, features of abuse were found.

Children may not die from falls from a height(Williams 1991, Roshkow et al 1990 and Barlow et al 1983). In examining causes of injury there is in addition the mechanism to be taken into account. Wilkins(1997) in a comprehensive review wrote of the variability in causes of injury and the determinants for severity associated with the mechanism. These include the distance fallen, the nature of the surface of impact and protective reflexes for forward and sideways impacts. A fall may be "broken", or the child may propel himself. The mass of the body and the head, and ratio is relevant. Dissipation of energy may occur, resulting in fractures which may protect the intracranial contents.

The impact may be focal, over a small area or point, or diffuse on a flat surface. Wilkins(1997) reviews the literature on the dynamics and biomechanics, and considers how this can be matched to cerebral damage. In children there are clearly complex interactions, and the history of the event may be difficult to obtain.

It should be remembered that what initially appeared a minor injury could have a serious or fatal outcome, such as extradural haematoma. Minor or moderate injury can be subject to secondary insults. Children respond to cerebral injury differently to adults as reported by Humphreys, Hendrick and Hoffman(1990).

When compared with adults the young child sustains a higher percentage of skull fractures than adults, perhaps as a result of top heaviness together with anatomical susceptibility.

There are many situations in which falls occur, which are the result of the use of play equipment, recreational toys and learning aids which may significantly affect the severity of injury. One of particular concern is the baby walker. This has been provided as a passive minder, a source of activity and an encouragement to learn to walk, though in fact it does not have this benefit. With the infant on board, all is well on a level surface. The top heavy infant however, if the walker tips over, or down stairs, goes at speed head first with the primary impact being on the face or head, with resulting skull fractures and related head and facial injuries.

Falls, which cause injury to toddlers and preschool children, are most commonly within the home environment. MacKellar(1989) discussed the need to examine domestic interiors in the context of accident prevention. Falls may be part of developmental experience. However as in many other accident situations, parental supervision and education for the most vulnerable could prevent injury.

There were three baby walker injuries identified in the Monklands Co-ordinated Study.

2.(a) (2) Road Traffic Accidents

Pedestrians

Injury to children is influenced by the age, development both physically and psychologically and the environment in which they are obliged to exist. Children are dependent to a greater or lesser degree on adults for their safety. Unsupervised they tend to be impulsive, constantly mobile, unaware of danger and forgetful of lessons given on risks(Demetra 1992). The ability of children to perceive danger and their reaction to it may be very limited. There may be difficulty in comprehending environmental variables, and estimating the speed and distance of approaching vehicles Pedestrian accidents mainly affect the preschool and school children, male children predominating in all ages(Rivara and Barber 1985, Rivara 1985, Guyer , Talbot and Pless 1985). Sex related behavioural characteristics are thought to be influential. Males daring, impulsive and extroverted are also less able to cope when threatened. As in bicycle accidents, childhood behaviour is a major determinant in pedestrian traffic injury. It is more common in urban areas, and where the street is literally the play area. Social deprivation is not infrequent and lack of adult supervision and control is a major factor. The toddler and preschool child unsupervised or controlled has virtually no comprehension of traffic safety skills(Hoffman, Payne and Prescott 1980). The majority of pedestrian injuries occur in daylight hours, in late afternoon and on week days. This coincides with journeys to and from school(Stevenson et al 1992).

The actual mechanics of car/child impact depends on a number of factors, including the development, size, shape and height of the victim. Most commonly the impact is on the bumper. The child is thrown in the air, strikes the windscreen or roof, depending upon the speed of the vehicle, and as the car slows the victim rolls off striking the head on the ground. Speed is a major factor in the first impact. The slower the speed the less the risk of serious injury. The types of injury sustained from pedestrian motor vehicle contact is direct impact to the head, usually with skull fracture and intracranial injury.. In slow impacts a local injury may be complicated by an extradural haematoma. In contrast severe cerebral trauma can occur from inertial forces without fracture which produce diffuse axonal injury and subdural haematoma(Guthkelch 1971).

Fatal pedestrian accidents are more common than fatal occupant injuries in the preschool child, particularly in urban areas. Many agencies have been involved in research on initiatives to reduce pedestrian injury. There is a clear difference between the child occupant, who is a passive and dependent participant and the child pedestrian who is almost always acting independently of an adult.

Tanz and Christoffel(1985) examined the risk factors for pedestrian injury. They found, as had others before, that male children dominated, though there were no differences in the exposure to the traffic situation. The age groups most commonly affected were preschool and school children. Emotional and behavioural problems have been identified with poor interpersonal skills. Male children have more adjustment problems. Girls are said to be more accident prone. Tanz quotes a child with a constellation of behavioural traits, combined with an activity level and adventuresome spirit who is more likely to be involved in dangerous situations. Adjustment problems and attention deficits means that the child may be less able to cope with the traffic situation(Agran 1987).

As protection for child occupants increases the proportion of serious head and other injuries from pedestrian accidents is likely to increase. A wide range of accident prevention strategies has been identified.

Occupants

The neurotrauma occurring as a consequence of vehicle occupant injury depends in part on whether the victim is restrained or not. The occupant is travelling at the speed of the car. If the speed is suddenly reduced or arrested, the unrestrained child continues to move at the original speed, strikes the interior of the vehicle or may be ejected. The injury sutained by the head is high velocity impact trauma.

By contrast inertial forces can produce severe injury without significant contact and without skull fracture, but with subdural haematoma, diffuse axonal injury, vascular ruptures and contusions. The forces may be complex with angular and rotational forces added to the initial movement.

The introduction of legislation over the past two decades relating to the fitting and use of restraining seat belts, harnesses and child safety seats has proved effective in reducing injury. The restraints have been designed to adapt as the child increases in age and size. The improvement in protective effects has been reported in North America, Australia and the U.K. There have been concerns however not only of the failure to utilise, the protective equipment fitted, but reports of misuse of seats, particularly for instance in toddlers. Bull, Stoupard and Gerhard(1988) reported a fatality and reviewed the US literature.

Avery and Hayes(1985)reported on death and injury in cars in children from data collected between1978 and 1982. The highest mortality was for children aged 1-2 years. The casualty rate was lowest under 1 year of age increasing to a peak at 3-5 years, unlike the U.S. report of a very high mortality for children under the age of 6 months in cars. The effects of legislation introduced in the U.K. were examined. 25% of children were provided with restraints compared with 90% of adults. Nevertheless there was a 14% decrease in severe and fatal injury following the legislation affecting front seat restraint.

Avery and Hays(1985) concluded that children were safer restrained in front compartments than unrestrained in the rear. The authors emphasised benefits of in-car restraint of children, quoting the work of Lowne et al(1984), Pearne(1978), Geddes and Appleton(1982) and Christopherson and Sullivan(1982).

Rear seat belt legislation has been enacted subsequently in the UK, but recent surveys undertaken by the Author (MTB) show a depressing number of children still travelling unprotected often standing in the rear compartment behind the front seat-belted occupants. Agran(1987) undertook a survey of nine emergency rooms in Orange County California to assess the effects of the introduction of seat-belt restraints on the care of infants and children. She examined the statistics for the two years before the introduction of legislation and the two years after. The results showed that in the child population under the age of seven years covered by the legislation there was an increase in use from 28% - 50%. There was also a significant decrease in the number of children injured. Head injuries decreased by 17%. The surprising and unexpected fact which emerged from the analysis, was that despite the reduction in injuries there was no matching reduction of attendances in the emergency room. This was attributed to the necessity perceived by parents, paramedics and police for "a check-up just to be sure". It could also of course have been influenced by the association with third party litigation and insurance claims following an accident.

One of the interesting developments in recent years has been the increase in off road motor vehicles and motor cycles. Children involved in activities in which only a minority are likely to participate, are unlikely to attract much public concern. This is likely to be also a fact where the accidents occur on private property, where legislation may not be applicable. There has been an increase in the UK in accidents involving off road motor cycles and dirt bikes. The vehicles are sized down to accommodate quite young riders. Protective helmets may be worn, but patterns of injury are similar to motor cycle injuries in adults. Males dominate in these activities by a ratio of 4:1.

Cardoso and Pyper(1989) reported injuries on 375 children, 83 with head injuries. Males dominated 5:1 and the average age was 10.4 years. The number of head injuries increased from 5 in 1980 to 23 in 1985. The commonest cause was loss of control of the vehicle. Only 7% of the injured were wearing protective helmets. The environment in which the accident occurred was frequently rural; sometimes the off road vehicle was related to farming, mining, tracking and logging activities. There has however been a definite increase in the use of such vehicles for recreational purposes. Concomitant has been an increase in all types of injury, and in the paediatric mortality. Others have reported paediatric injury due to off road vehicles. Cardoso and Pyper(1989) discussed the implications for the use of these vehicles, and made recommendations for improving safety.

Bicycles

Bicycles are popular with children as recreational objects, and also as a means of transport. In both groups the cyclist may be brought into contact with motor vehicles, increasing the risk of injury in the event of an accident. Bicycles were reported to be the reason of 400,000 child emergency room visits in the United States in 1986 and the cause of 500-600 deaths. Children under adolescence are most commonly involved. Kraus, Fife and Conroy(1987) reported a population based study of bicycle related brain injuries in San Diego, California. He stated in 1982 there were 900 deaths and half a million attendences in emergency rooms as a consequence of bicycle related injuries. 70% of those killed or injured were under 15 years of age. Gallagher et al(1984) reported 10% of emergency room attenders with bicycle related accidents, had sustained head injury. Serious head injuries were identified in 90% of fatal bicycle related injuries by Fife et al(1983). Kraus, Fife and Lonroy(1987) reported bicycle related head injury as 7% of 3,358 cerebral injuries, 86% were mild, 12% were moderate and 2% were fatal. The maximum incidence was in 5-9 year old females, and 10-14 year old males. Under 14 years there were 153 bicycle related brain injuries, 22% of all injuries in this age group.
Bicycle injury involving motor vehicle accidents occurred half as often as cycle accidents alone, but the injury rate was 3 times as high in males. 69% of injuries not involving motor vehicles and 45% of motor vehicles occurred in persons under 14 years of age. The injuries involving motor vehicles were more serious, the hospital stay was longer and outcome was less satisfactory. The incidence of brain injury reported by Kraus(1987) is similar to other reports form North America(Guichow and Myles 1976). All the authors reported greater severity of injury where a motor vehicle is involved(Freide and Azzara 1985). However not all bicycle only minor injuries had a good outcome. This suggests that complications supervened on relatively minor injury modifying potential good recovery.
Bicycles are used most commonly in the summer months for recreational purposes, with maximum usage between May and September. Males dominate and the 10-14 year olds are at greatest risk. When the bicycle is used for transportation and on the highway the incidence of bicycle/motor vehicle impacts increases(Spaite et al 1991). Accidents most commonly occur as a result of loss of control of the bicycle or in collision/impacts with objects. Where motor vehicles are involved it is often the failure to observe, or ignorance of, traffic regulations that causes the accident.

Increased volume of motor vehicle traffic makes the environment less safe for the young and inexperienced cyclist.

The injury to the head is the major cause of serious injury and death(Fife, Dais and Tate 1983) and the majority of fatal head injuries resulted from blunt trauma. Subdural haematoma was frequently the pathology. Children who were injured on bicycles were found by Illingworth,(1981)) to be injured on more than one occasion. She suggested that the Accident & Emergency attendance provided an opportunity for education and prevention.

In Australia Reynolds and Cohen(1987) commented on studies that had identified 65%-75% of bicycle accidents involving children. Failure to observe traffic regulations was identified as a significant and contributory cause. Weiss(1986) reported on 150 children injured on bicycles and stated that they represented 20% of all admissions with head injury, second after falls. They examined the use of protective helmets in the injured group and found only two were protected. This may be lower than the use in children who were not injured, or not admitted to hospital. There is no comparison between the admitted group and the emergency room group. The author's survey of bicycle use found that the ownership of a helmet did not guarantee its use. There was definite reluctance on behalf of the young male cyclist to wear a helmet even if it was available. The author suggested various accident prevention and education strategies to increase usage. Rivara's(1987) report on non vehicle related bicycle accidents still found that head injury was common in bicycle accidents. He too noted reluctance by the child and adolescents to take up the benefit of helmet protection.

2.(a)(3) Sports Injury

Sports injuries resulting in cerebral trauma in this survey were predominently team sports soccer and rugby. Soccer was commonly played informally. The impacts were most frequently on the ground, on items of equipment and the results of tackles and collision of heads. Falls were common, males dominated, and competitiveness and aggression may have contributed. Sports and play was not specifically differentiated. No review is indicated.

2.(b) Mechanism of Injury

Injury to the head and to the intracranial contents is the result of the application of force or forces, the effects of which may be modified by the characteristics of the skull as a rigid, non-expandable container. Within the skull the brain, at various stages of maturity in the paediatric group, is suspended and surrounded by cerebrospinal fluid. The application of force results in distortion, tearing and rupture of intracranial structures, which may be focal, diffuse or a combination of both. The rupture of blood vessels, results in haemorrhage, which can vary from petechial lesions to expanding masses or haematomas. The absence of any safety valve system, in all but the infants skull, or one with a skull defect to the exterior results inevitably in raised intracranial pressure.

The biomechanics of head trauma have been the subject of experimental work involving primates(Stalhammer 1990). The knowledge acquired has been most extensive in its application to adults, rather than to children at the various stages of development. The results of trauma by various agents and forces have been described by Gurdjian and Gurdjian(1978). Direct and indirect forces are causative agents in mechanical injuries to the head. Direct impact occurs when an object strikes a non moving or slowly moving head. Alternatively the moving head may strike an immobile or slowly moving object.

Indirect injury may result in forces transmitted from impact elsewhere, as in falls from a height, with force transmited through the calcaneum and lumbar spine. Landing heavily on the buttocks may transmit significant force via the spine to the skull, which may fracture around the foramen mangum, and the brain may be simultaneously injured.

Movements of the unsupported head, resulting in forced flexion or hyperextension, without a direct blow may result in intracranial damage. When force is applied to the head, one or more effects can be produced - compression, acceleration or deceleration, or in various combinations. The deformation of a thick skull at the point of impact may result in compression.

Impact acceleration of the head occurs when it is free to move. Impact deceleration is the abrupt cessation of movement, when it strikes an immobile object. Both acceleration and deceleration are associated with compression, greater in the deceleration impact. The effects of acceleration/deceleration are different. With impact deceleration there may be extensive deformation and compression, at the moment the movement of the head is arrested. In impact acceleration there is initial compression as the head is forced to move.

In the artificial conditions of laboratory research, the effects of individual forces can be observed in isolation. In real life trauma there are usually combinations of forces applied. Precise information may not be available, but may be inferred from the history of the event. The combinations of linear or rotational acceleration forces produce complex clinical effects.

2(b)(1) Impact Injuries

Impact on the head, the result of the moving head striking an immobile object, or a moving object striking the relatively immobile head, will produce evidence of injury, most obviously at the site of the impact. The scalp, struck by a hammer will be injured and the result may be splitting, shearing and or compression. If the force is sufficient, the underlying skull may be deformed and may fracture. The underlying structures may be subject to inertial stress, and may be damaged. If the forces are sufficient, injury may occur at a point some distance from the impact.

Direct compression injury of the head between fixed points is the most rare of the mechanisms and acceleration/deceleration forces are minimal. In blunt impact inertial stress propagation is important in the mechanism of injury.

The different densities in the intracranial contents are also relevant. Following impact there is a movement of the brain over the surfaces of the skull, and within the restricting membranes, which results in contusions, bruising and coup and contra coup damage.

Details of the G force applied, the rise in intracranial pressure and the velocity have been measured and reported.

The damage sustained as a result of impact force applied, occurs immediately, and is irreversible. The response to injury may cause further deterioration due to haemorrhage, swelling and vascular responses. Some of the responses may prove difficult to control or modify. The addition of responses to trauma elsewhere in the body may add avoidable secondary insults, which compound the primary biomechanical agents.

2(b)2 Penetrating Injuries

High velocity missile injuries, are most frequently observed as a consequence of fire arm misuse and are infrequently seen in the Accident & Emergency Departments in the United Kingdom.

Low Velocity Penetrating Wounds

Though unusual in comparison to other mechanisms observed in this Study, penetrating injuries do occur in childhood. They often result from falls upon sharp objects, occasionally result from assault with a sharp weapon and sometimes are the result of penetration by air gun rifle pellets(Shaw and Galbraith 1977). These may pass through the skull, particularly at its vulnerable points in the temporal and orbital regions. The depth of penetration, may be a feature of the distance from the weapon or the mode of propulsion. It is not unusual that the child may be unaware of the cause of the wound that he or she has sustained. The seriousness of the injury clearly depends on the depth of penetration and the area of the cerebrum involved. Lawn darts are a source of penetrating injury(Sotoropoulis et al 1990).

Advances in knowledge on the biomechanics of head trauma have been made by Gennarelli and Thibault(1985) and his colleague using primates, and subjecting them to a variety of mechanical insults. Additional information has in the past been derived from pathological studies(Hume Adams 1990). CT and MRI scanning is constantly adding further to the knowledge of changes resulting from the various mechanisms of injury. Gennarelli(1985) has stated that diffuse brain injury results from the effects of head motion, most commonly associated with impact. The influence of the impact on the head is that it results in acceleration and deceleration of the head and its intracranial contents. The severity of the injury is determined by the direction, magnitude and speed with which the head moves either from rest or to rest during the injury sequence. It also influences the type of pathology sustained.

The violent forces to which brain tissue is subjected produces strains and distortions, which result in shearing, stretching and rupture which characterise diffuse axonal injury.

Gennarelli(1990) states that up to a point the acceleration/deceleration is the most important factor in determining the extent of brain deformation and subsequent damage.

Diffuse injury and the force applied relates directly to the level of concussion sustained. However the more severe the injury the more relevant is the direction in which the force is applied to the head. In severe diffuse axonal injury the forces applied in the coronal plane lead to lateral head motion. At equivalent or even higher acceleration in the sagittal or horizontal plane, only mild to moderate diffuse axonal injury occurs. The application and nature of the forces applied have a direct effect on levels of consciousness. Cases with a transient loss of consciousness, were believed to occur without permanent structural change, though the precise physiological mechanism is not known. The spectrum of concussion from transient loss to deep and prolonged coma correlates not only with the acceleration/deceleration applied, but with the directional movement effected.

Gennarelli has described a continueum of brain injuries. As mechanical strains increase, classical cerebral concussion and diffuse axonal injury follow the mild concussions. Disorder of the brains functional activity is always more extensive and common than the anatomical disruption (as previously identifiable). Technical progress, CT and MRI scanning has its application to the clinical situation.

The relevance of the biomechanics of impact to the assessment of the head injured patient in the Accident & Emergency Department was examined by Yates et al(Yates and Peters 1986, Yates, Hadfield and Little 1987). He suggested that in addition to the neurological assessment, and the scalp features of bruising and swelling, the mechanical factors might have a value in identifying which patient might be at risk of developing complications, particularly those in association with skull fracture.

An analysis was undertaken of all the head injured attenders at two Accident & Emergency Departments over a 12 month period. In addition to the information normally collected, special consideration was given to the speed of impact, and the physical feature of the object or surface on which the head came into direct contact.

Three criteria were used to assess the severity of injury, the state of consciousness on arrival, the period of post-traumatic amnesia and the detection of a skull fracture.

The site on the head at which the impact occurred was also ascertained and recorded.

Yates(Yates, Hadfield and Little 1987) commented on the relative lack of interest and information recorded on the biomechanics, and suggested this was because in the emergency clinical setting there was likely to be no finite method of measurement. Quoting Gennarelli he said that the nature, severity and direction of forces applied to the head at different sites, were all important determinants of the response and the type of brain injury sustained.

Yates(1987) sought to correlate the experimental knowledge, to patients following head trauma. He suggested the impact characteristics and the detection of a skull fracture might be of value in identifying patients at risk of secondary complications particularly intracranial haematoma.

The clinical profiles were comprehensive. The biomechanical data was classified under

1. Speed of impact, high, medium and low.
2. Contact agent.

This was sub-divided into blunt/soft, blunt/hard and sharp (the sharp injuries were not compatible in his cases with the definition used in this Thesis (MTB).

Yates et al(1986) analysed results on 60,000 patients, and placed them in his predetermined categories. They were then subject to statistical analysis.

Post traumatic amnesia and skull fracture was regarded as a measure of the severity of impact. When post-traumatic amnesia was matched against the impact agent there was a significant association between blunt/soft trauma 15%, and blunt/hard trauma 20% whilst only 3% with sharp trauma had post-traumatic amnesia.

When the duration of post-traumatic amnesia was correlated with the site of impact, no difference was observed between the parietal, temporal and occipital areas of the skull. Frontal impacts were associated with a significantly shorter duration of post-traumatic amnesia. 9.5% of patients with no recorded external injury had post traumatic amnesia in excess of five minutes.

When Yates et al(1987) examined the evidence for bony injury at the scalp site, he found fracture was most common in the temporal 5.3%, parietal 4.5%, occipital 3.4% and frontal 1.3%, in adults.

When the speed of impact was related to skull fracture it was found that 11.3% of fast impacts had a fracture as opposed to 0.16% with slow impact.

Four patients had skull fractures with low impacts. Three were children. It was suggested that the history might be unreliable. The age of the children was not recorded, nor was the possibility of abuse considered. The comment was made that the record review suggested that the injury was incompatible with the history.

In discussing his results Yates suggested that post traumatic amnesia was considered the yard stick of severity of injury.

The detection of fracture however was of value in alerting the clinician to the risk of intracranial complications including intracranial haemaotma, but also depressed fracture, particularly when associated with focal impact and scalp injury. The results identified high speed as a factor in post-traumatic amnesia and skull fracture. More patients had longer periods of post-traumatic amnesia when subjected to impulsive loading forces without scalp contact. The author supplemented the guidelines issued to the casualty medical officers in the two hospitals participating in the research, to take into account the findings of this piece of research.

Berney et al(1994) recently analysed epidemiological data on 1,812 children attending hospital in the city of Geneva. The age range was up to 15 years. The authors divided the patients into three groups by age - 0-3 years, 3-9 years and 9-15 years. The youngest group was further sub-divided into infants under one year and toddlers 1-3 years of age. Male and female children were separated for analysis. The authors sought to assess biomechanical factors on clinical signs, outcome, the energy applied and the severity of the brain lesion.

The energy or force involved in the injury event was graded as low, medium and high. The injuries were categorised into five types varying from benign, 1,503, subdural haematomas eight, extradural haematomas 25, contusions 257 and 19 open brain lacerations.

The authors used a predisposition ratio to examine and report their correlations. When the child groups were matched to the cerebral pathology, it was found that babies and toddlers were most likely to sustain low energy trauma, but to sustain more skull fractures, more subdural haematomas and benign injuries. Less frequently did the infant and toddler lose consciousness, and they were less frequently in coma, compared with the older children. More often the youngest have lateralising signs and early seizures.

The children in the 3-9 year old group had higher energy accidents, associated with contusions and open lacerations. Extradural haematomas were more prone to result from low energy accidents.

Fractures were associated with higher energy accidents, particularly when the base of the skull was involved. The sex distribution of fracture was surprising being higher in girls, 31% than boys 25%. Girls were also more prone to coma in this middle age group.

The examination of cerebral lesions, presumably by CT scanning showed contracoup lesions were rare 1.4%, particularly in the youngest children. The risk of contra coup increased with age, and with a high grade energy force.

The authors examine the history or presence of impaired conscious level and the frequency with which the lucid interval was recorded. The latter occurred with almost equal frequency in each age group, and for each grade of energy. The lucid interval was five times more frequent in the presence of a fracture, than in its absence and occurred 2.5 times as often with a cerebral contusion than with an extradural haematoma. More than 66% of extradural haematomas had a lucid interval compared with 25% with subdural haematomas. In this report every extradural haematoma was associated with a fracture, and secondary deterioration occurred five times more frequently in the presence of a fracture than in its absence. The frequency of skull fractures in the youngest group, by contrast, was not associated with a high incidence of extradural haematoma.

3 Loss of Consciousness

The importance of a history of loss of consciousness and its duration is that it forms the base line for continuing observation, and identifying improvement or deterioration. The history may be less than reliable in childhood, unless a witness observed the injury.

The methods available for assessing consciousness in the past, varied according to the cause of the coma, non-traumatic and traumatic, and the nature and severity of the head injury. There were also variations, depending on the location in which it was being undertaken, the home, the emergency department, ward or neurosurgical unit.

The assessment of the head injured patient requires a system to monitor consciousness. Various methods have been used over the years. The most difficult aspect has been observer variation and standardisation of recording. The value of an aide memoire is well established(Marsden and Price 1987). Important is the need to use a system, which allows the patient status to be recorded, in such a way, that the information can be transferred between attendants, and which facilitates communication between units. Changes in the patients neurological and general status can be recorded and trends for improvement, and more importantly for deterioration, observed and acted upon. In addition, Coma Scoring can be used to predict outcome, particularly in severe injury. Different methods of management of coma can be compared in different groups and centres thereby assisting research.

The Glasgow Coma Scale was introduced in 1971by Teasdale and Jennett to assess and record changes in the conscious state. It measured eye opening, verbal and motor responses, functions which were allocated a number on a scale of 5. It allowed consistent and reliable bedside observation of the degree of impairment. It brought greater precision to individual observation, allowed continuous monitoring by different members of attending teams, and defined a level of consciousness, and its progress and duration. When the individual numbers were aggregated, a Score was allocated 3-15. The system was initially devised to predict outcome. However having been tested in Glasgow, Holland and the United States, it achieved wide acceptance by those responsible for head injury care.

The basic scale and scoring system was added to conventional recording of pulse, temperature, blood pressure and motor activities in the limbs. Pupil size and responses were included. Despite an initial impression of complexity, the Glasgow Coma Chart has found acceptance with the nursing and medical staff in Emergency Departments, Wards and Neurosurgical Units.

Gentleman and Teasdale(1981) subsequently conducted a survey on its usage, and suggested that its success was partly attributable to the mobility of junior medical staff trained in its use. Their favourable acceptance and evaluation helped with its dissemination.

Despite its extended application over more than two decades, its consistency of recording and reproducibility has been challenged by Rowley and Fielding(1991). They claimed unreliable results with occasional and inexperienced attendants. They also indicated that interobserver comparisons are insufficient to validate the Glasgow Coma Scale. Subsequently it was claimed that junior medical staff in Primary Hospitals did not utilise the Coma Scoring System effectively when transmitting information to neurosurgical colleagues.

Paediatricians and Neurosurgeons have sought to measure conscious levels in children. The Glasgow Coma Scale was intended for adults, but has been used in children over five years of age.

In infants and young children, knowledge of normal anatomical development and physiological responses are essential to evaluate any deviation produced by trauma. In an attempt to address the limitations of the Glasgow Scale for young children Simpson and Reilly(1982) introduced a modification to take account of difficulty in grading verbal and to a lesser degree motor responses in the young patient. Eye opening responses were applicable to all ages. Subsequently Simpson et al(1991) reported on evaluation of the Adelaide Coma Scale. The children were 0 - 72 months. The authors claimed that the scale has proved clinically acceptable in Australian hospitals. There are accepted limitations. It predicts a narrow range of responses in infants and young children. It is difficult to rank injuries in minor, moderate or severe classes. Its prognostic value may be less than the Glasgow Coma Scale for adults. Sixty children were examined to evaluate the conscious level. The initial test is made six hours after injury, too late to be of value in Accident & Emergency Departments. Twelve children were in Neurosurgery, and 48 in general wards. The authors claimed acceptance by users and consistency in application. The use of the Adelaide Coma Scale seems to offer for children under five years, a system of monitoring most closely akin to the Glasgow Coma Scale for adults. The problem is the relatively limited experience of Accident & Emergency staff of the comatose young child outwith Paediatric Neurosurgical Units. Staff are likely to be less efficient than the Specialist Staff described by the originators of this Scale.

In the child who is deteriorating, urgent resuscitation may include intubation using drugs, or the control of seizures using anticonvulsants which eliminate the possibility for serial monitoring. CT scanning is then essential.

The child admitted for observation without impairment of conscious level may benefit from the Adelaide Coma Scale if deterioration occurs. The staff caring for the child will need to be trained in its use and to be applying it in children on a regular basis to sustain reliable and consistent readings.

TABLE 3 (i) THE GLASGOW COMA SCALE

A METHOD OF ASSESSING AND RECORDING THE LEVEL OF IMPAIRMENT OF CONSCIOUSNESS IN ADULTS

EYE OPENING	
Spontaneous	4
To verbal command	3
To pain	2
None	1
Best Motor Response	
Obeys verbal commands	6
Localises pain	5
Flexion withdrawal	4
Flexion/abnormal (decorticate)	3
Extensionabnormal (decerebrate)	2
None	1
Best Verbal Response	
Orientated, talking	5
Disorientated, talking	4
Inappropriate words	3
Incomprehensible sounds	2
None	1
Total	**3-15**

TABLE 3 (ii) GLASGOW COMA SCALE/ADELAIDE SCALE

ADULT SCALE		PAEDIATRIC SCALE	
EYE OPENING			
Spontaneously	4	As in adult scale	
To Speech	3		
To Pain	2		
None	1		
BEST VERBAL RESPONSE			
Orientated/talks	5	Orientated	5
Confused/talks	4	Words	4
Inappropriate Words	3	Vocal Sounds	3
Incomprehensible Sounds	2	Cries	2
None	1	None	1
BEST MOTOR RESPONSE			
Obeys commands	6	As in Adult Scale	
Localises pain	5		
Flexion withdrawal	4		
Flexion abnormal (decorticate)	3		
Extension/abnormal (decerebrate)	2		
None	1		
		Birth - 6 months	9
		6 - 12 months	11
		1 - 2 year	12
		2 - 5 year	13
		5 years	14

The normal aggregate Score will be as shown.

TABLE 3 (iii) SIMPSON AND REILLY SCALE

	SCORE
Under 6 months best verbal response is a cry	2
6-12 months comprehensible sounds	3
12 months recognisable words	4
Orientation is expected at 5 years	5
When the motor response is assessed a 5 point scale is used	
Under 6 months - flexion to pain	3
6 months - 2 years the child can locate pain but will not obey commands	4
The aggregate scores are	3-11

Other methods of assessing conscious level and charts may improve the quality of observations following head trauma, particularly in severe injury as shown in Appendix 3

4(a) Scalp Injury

The presence of a scalp laceration, or other visible or palpable evidence of tissue trauma, confirms that the head has been subject to a blow. Scalp lacerations, particularly in children are common, they may be regarded as of little significance, in relation to cerebral trauma. However studies, and day to day observations, suggest that certain scalp features, may have significant associations with skull fracture, and intracranial abnormality or the risk of complication.

Specific studies in children alone are not a feature of the available literature, other than reports from the Scottish Group(Strang, MacMillan and Jennett 1978, Swann, MacMillan and Jennett 1981) and the research of the Author, published by Ballantyne et al(1986). Fullarton et al(1987), in a study of 661 adults, but with some features relevant to children, examined the characteristics of open scalp wounds in an Accident & Emergency Department. 84% were found to be contused, and caused by falls 34%, and assaults 40%. The author sought information on the integrity of the scalp aponeurosis, and the ability of the casualty officer to predict the presence of a skull fracture. Incised wounds 16% were commonly due to assault. The galea was divided in 18% of patients. Fullarton found that 78% of the fractures were present in this group. Only two patients with an intact aponeurosis had a radiological fracture. Fullarton used wound exploration as a method of detecting underlying skull fracture. The Casualty Officers claimed that nine fractures were detected in this way. These were not subsequently confirmed on xray evaluation. This may have been due to imperfect xray techniques, or clinical error. If the fractures were depressed, the appropriate views may not have been requested? Fractures involving only the outer table of the skull, are difficult to distinguish on xrays of the skull. The risk of such fractures is undetermined. The exploration of wounds, particularly short lacerations, are extremely difficult in an uncooperative child, under local anaesthesia. To visualise the fracture, as opposed to palpating it, the scalp aponeurosis must be divided. To detect a fracture in this way it is necessary that it underlies the wound, which according to McKissock et al(1960) it may not.

In an examination of 3,971 adult and child patients with head injury, attending Monklands District General Hospital, Ballantyne et al(1986) found 63% had a scalp wound, 50% being lacerations. 13.7% were more than 5 cm in length and penetrated the galea. Females had a lower incidence of scalp wounds than males. Children under 12 years presented most commonly with scalp swelling. The utility of skull xrays was 69%. 67 fractures were diagnosed, twice as many in males. Depressed fractures were more frequent in adults 40% than in children 12%. 84% of the depressed fractures had a scalp wound, whilst 79% of the linear fractures were compound. Ballantyne demonstrated a statistically significant association between skull fracture and long galeal lacerations. The laceration with these characteristics is a marker of depressed fracture. Linear fractures were significantly associated with swelling, contusion and abrasion. Four depressed and 25 linear fractures occurred in 59 adults. In 636 children, three depressed and seven linear fractures occurred. The depressed fractures in children were associated with swelling. Analysis showed fracture risk was increased three times with swelling. Long, deep galeal lacerations increased the fracture rate by 18 times. It was concluded that scalp features, other than galeal lacerations, and swelling abrasion and contusion, were poor predictors, in isolation, of skull fracture. Had xrays been requested in the presence of these features only, they would have revealed 56% of the linear and 52% of the depressed fractures in the skull xrays taken in the Accident & Emergency Department. It was suggested that these features might act as indicators for selection for skull xray.

In the current Study (Brookes 1999 publication pending), 5993 children were examined for evidence of injury to the scalp. 5110 children had such features of injury. The nature of the trauma varied in the different age groups. Skull xrays were requested, even when no injury was confirmed. The scalp injury was matched to the skull fractures, confirmed by a radiologist, at different ages.

Statistical analysis subsequently confirmed that lacerations penetrating the galea, of whatever length, demonstrated a significantly higher risk of fracture. Such scalp injury is five times more likely to result in a fracture than children with other injuries.

By contrast superficial lacerations carried a lower than expected risk, about a quarter is likely to result in skull fracture as other scalp injuries.

Children with scalp lacerations/abrasions and contusion had a higher than expected number of fractures.

The nature of scalp injury varied with age, and therefore risk of skull fracture.

The statistical methods employed were also used by Quayle et al (1997). They found a scalp laceration, contusion or abrasion was considered a significant factor for skull fracture only in infants. They stated scalp haematoma was a significant predictor of fracture in children younger than two years. Their cohort included all grades of cerebral trauma, and cannot be compared to the children in this Study(MTB).

These authors however identified skull fracture as an independent predictor of intracranial injury, the risk being four times greater, though intracranial injury occurred in its absence.

In an earlier Accident & Emergency Department report Maitra(1981) had examined scalp injuries in both adults and children. All the lacerations in 910 patients were under 5 cms in length, but no further detail was given. The absence of a scalp feature was associated with admission to hospital in 26% of cases, and in only 4% of those discharged home, suggesting a relationship with cerebral injury.

Masters et al(1987) in categorising patients for selection for skull xrays had placed scalp injuries in the low risk group, unless depressed fracture was suspected. Children were however consigned to the medium risk group, where discretion was allowed. The problem with this view is that if one suspects a depressed fracture is present, and takes the appropriate action there is no problem. It is in the patient with a scalp laceration who feels well, gives no history of loss of consciousness, and has no cerebral impairment or neurological abnormality that the compound depressed fracture may well be missed(Miller and Jennett 1968, Sande, Galbraith and McLatchie 1978).

Depressed fractures with the life threatening risks of intracranial infection are discussed in detail in the relevant section. Children were referred to by Leonidis et al(1981) in his discussion on the value of skull xrays. In a review of 354 patients who had skull xrays 40% had scalp haematomas and 25% scalp lacerations. Leonidis reported that the presence of a scalp haeamatoma in a child increased the likelihood of a skull fracture by 1.5 times, and included it in his criteria for skull xray. He found however that scalp lacerations had a negative association with skull fracture. This may have been related to the very minor nature of the injury, only 67 of 137 lacerations required suturing. He too suggested palpation through the wound. This seemed somewhat impracticable as the wounds were, in the majority, too small to warrant stitching. He suggested that further study was warranted. Boulis, Dick and Barnes(1978), evaluated the need for skull x-rays in an analysis of 1,000 skull xrays in children and recommended xray for those with scalp lacerations, lest a fracture, underlying a wound be missed. Risks of infection and depressed fracture were a cause for anxiety to these authors.

Sainsbury and Sibert(1984)reporting on a series of 28,701 children with predominantly minor head injury, found that the presence of a boggy scalp haematoma was strongly suggestive of intracranial haematoma, whether a fracture was present or not. This phenomena had previously been described by Ingraham Campbell and Cohen(1949) who had claimed it was a good indication of the location of intracranial haematoma. This clinical feature was used as a predictor of location even before radiography by Hooper(1959).

Tunturi et al(1982) examined 598 patients using 16 variables in a search for predictors of skull fracture and found a scalp wound was significantly associated, MacKellar(1989) in a study of children in an Accident & Emergency Department, identified scalp wounds numerically, but did not relate them to complications. Mitchell et al(1994) in a study of minor head injuries, found deep scalp wounds were a predictor of abnormality on CT scans.

The presence of a scalp haematoma was included in their Guidelines for skull xrays by the Royal College of Radiologists(1993), and those of a Group of Neurosurgeons(1984).

Any scalp wound should prompt consideration of both penetrating injury and a foreign body. A significant mortality can be associated with such injuries, including air gun pellets(Shaw and Galbraith1997) and lawn darts(Sotiropoulos et al 1990).

4(b) Site of Injury

The literature is not rich in reports relating to studies on the site of injury to the skull, but there are many incidental references in papers on various head injury topics. The site at which trauma occurs, is affected by the mechanism of injury, and the age of the child. Infants, with a higher risk of fracture than older children, sustain injury most commonly at the parietal site. The toddler and preschool child tends to fall over forwards, a feature of top heaviness, and early efforts at independent locomotion. As activity becomes more varied, many interactive forces operate. The site of injury is important because of the complications, which may result particularly when a fracture is sustained. The location of the impact may result in injury to arterial and venous channels, may open into air sinuses with the risk of infection. Base of skull fractures may be associated with cranial nerve damage and in severe impacts the brain underlying may be extensively injured with a focal neurological deficit e.g. speech or seizures. Damage immediately related to both the impact - coup, may be associated with secondary injury at some distance - contracoup.

Vogel(1976) produced an exposition of the anatomical features of the calvarium the adherence of the dura, and the location of the middle meningeal artery and its branches. The tenacious nature of the relationship between bone and the dura allows the vessels to be torn, commonly associated with a fracture. These features alter at different stages in childhood. The relative fragility of the skull, was emphasised, at the temperoparietal region. This may result in a fracture without the application of particular force. Arterial bleeding may result in a rapidly expanding haematoma, with shift and tentorial herniation. Coppola(1973) had expressed concern that fractures at the temperoparietal site implied high risk and urged vigilance and routine admission.

Garniak et al(1986) examined the xrays of 1000 patients and found 18 fractures in 13 children. The locations were parietal in eight, temperoparietal in four, occipital four and two were not identified by locus. Whilst Garniak expressed a view that skull fracture did not alter management, he made exceptions for the school aged male child with a temperoparietal fracture. Piertzak, Jagoda and Brown(1991) reported injury associated with a large scalp haematoma at the parietal site. There had been a report of apparently minor trauma in an alert child. Skull xrays showed a depressed fracture and CT an underlying haematoma. Piertzak et al concluded that xrays were indicated in the infant and young child because of the anatomical characteristics of the skull. The risk of abuse in this age group and the diagnostic features of the skull films was emphasised.

Bonadio, Smith and Hillman(1989) correlated the site of skull fracture, and the risk of epidural haematoma. They reported 34 parietal skull fractures, with a 10% incidence at the parietal site of epidural haematoma, as opposed to 1% at other sites. Hendricks et al(1964) reported a parietal location for 50% of the skull fractures in his large series of admitted children.

Yamamoto and Ogata(1984) in a study on headache and vomiting in childhood, found occipital injury was common in association with vomiting and suggested a causal relationship.

Occipital injury, with and without fracture is commonly seen in the condition of post-traumatic transient cortical blindness and is associated with EEG changes in the occipital lobes.

Although much controversy has been generated regarding the significance of skull fracture and haematoma, more than 90% of extradural haematomas are associated with a fracture and up to 75% of subdurals in children. The location of the fracture is helpful in alerting the physician to risk. Where the haematoma occurs at an unusual site such as the posterior fossa, the atypical clinical picture, may be clarified by the identification of a related fracture and urgent CT scanning may reveal the mass lesion.

The site of impact, influences more distant or contracoup injury. Occipital trauma may be followed by frontal and temporal contusion. By contrast frontal injury rarely causes occiptal contracoup damage, though it can too be associated with transient cortical blindness.

Yates, Hadfield and Little(1981) observed that frontal impacts were associated with a significantly shorter duration of post traumatic amnesia, in predominantly adult patients which they studied in the Accident & Emergency Department of Hope Hospital, Salford. The impact sites in his patients were associated with fracture as follows, frontal 1.3%, temporal 5.3%, parietal 4.5% and occipital 3.4%. Fast impacts, as defined in his study of biomechanics, were associated with 11.5% of the fractures, and slow impact 0.15%. The exceptions were children three of whom sustained fractures at apparently low impact speeds. Whether this represents greater vulnerability, or an inaccurate estimation of speed is not certain. Yates and

Peters(1986)related the site of injury and the force applied to the duration of post traumatic amnesia.

In childhood, fractures which appear to be incompatible with the mechanism, are bilateral, cross suture lines or show evidence of injury at different intervals, should raise the suspicion of the casualty medical officer to the possibility of child abuse. Urgent CT scanning is justified as many of these children will be seriously injured. Suspicion of the nature of any skull fracture may justify skeletal survey not only to ensure immediate and adequate treatment, but to protect the child from further injury/abuse.

5. Headache and Vomiting

Hugenholtz et al(1987) reported on a prospective study of 96 consecutive children, who were suffering their first head injury, mild in category, GCS 13 - 15. These were compared with a retrospective chart review of 29 seriously injured children whose GCS was 8-12.

The prospective study documented the events surrounding the injury, and included information relating to the time from the ingestion of food and fluid to the head injury. This followed the experimental work of Gennarelli et al(1980) which suggested that fasting primates, before concussive injury, reduced emesis.

The analysis of the 96 children included dividing them into two groups, those under two years of age and those older. The profile included the site of injury, the presence or absence of skull fracture, the location of any fracture and the interval from ingestion of food or drink to the head injury and also the frequency of post-traumatic emesis. Minor head injury proved more likely to produce vomiting than more serious head injury 50:28. When the interval from eating to injury was examined it was found that vomiting was more likely to occur, if a meal or snack had been taken within an hour of the trauma. Amongst the minor head injuries 65% over the age of two years vomited compared with 18% under two years of age. Children who had eaten more than an hour before the injury were significantly less likely to vomit regardless of age 33%:79%.

Those injured within 15 minutes of ingestion vomited and all who had taken food within one hour vomited. Thereafter there was a steady decline with only 25% vomiting after four hours of ingestion.

The authors found no relationship to skull fracture, or the site of injury. This Author had previously suspected occipital injury was associated with a tendency to vomit excessively. This was not confirmed in the Monklands 1 Study. Yamamoto and Ogata(1984) reported a high proportion of occipital injury related to emesis.

The views of Bruce and Schut(1982) that the syndrome was one of polar injury following an occipital blow with shearing and deformation of the brain stem, was not supported by the evidence of Hugenholtz et al(1987).

Gennarelli has reported significantly greater elevation of intracranial pressure in primates following acceleration/deceleration in the sagittal plane, which produces disturbance of the brain stem.

Hugenholtz et al(1987) also considered the role of pain and headache in the stimulation of the vomiting centre. The paper was of interest, but did not discuss whether the emptying of a full stomach might be beneficial. Repeated retching and vomiting is likely to raise intracranial pressure.

The effects of head injury on the vestibular system were not discussed. The neurological evidence in minor head injury does not indicate significant vestibular dysfunction, except perhaps associated with basal skull fracture which is usually in the moderate or severe, rather than the minor category.

The authors concluded that their evidence would allow management decisions to be influenced, particularly with regard to discharge home. They suggest that children who vomited after food taken within an hour of injury and were otherwise neurologically stable might be discharged after a few hours of observation. Those who vomit more than an hour after food, are likely to require a more prolonged period of observation and intravenous fluid replacement.

In children under two years, absence of emesis should not affect any management decisions.

The children who vomit after minor head injury, and who are seen as the data shows, soon after, are unlikely to be vomiting due to the mechanisms operating as a result of raised intracranial pressure. Bruce(1981) has shown that vascular engorgement from impaired autoregulation is relevant to severely injured children.

The opportunity to monitor intracranial pressure in minor head injury is unavailable, but Gennarelli et al(1980)has observed transient changes in intracranial pressure in mildly injured primates . It is suggested that this is due to a temporary loss of autoregulation which is compensated quickly. More protracted vomiting may be the result of biochemical factors released by the traumatic insult.

The differences seen in the children under two years of age and the older children may be a reflection of the immaturity of the brain and the myelination process.

There are also variable mechanisms of injury. The infants skull with its open fontanelles and unfused sutures might be better able to absorb the impact forces without transmitting them to the cerebrum.

The location of a vomiting centre in the reticular formation of the lateral medulla, suggests it may be vulnerable to mechanical forces applied. Emesis occurs when the centre is stimulated beyond a critical threshold and by a variety of stimuli, via the reticular activating system

It is of interest that Hugenholtz et al(1987) did not relate vomiting to the history of loss of consciousness, though at the time of examination the Glasgow Coma Score was 13 - 15.

The onset of vomiting was variable from minutes to hours. The authors related the manifestation to paediatric concussion syndrome.

Yamamoto and Ogata(1984) commented on infants and children who following mild head injury became pale, drowsy and vomited frequently. They suggested that the mechanism was different from that in adults, in whom raised intracranial pressure, subarrachnoid haemorrhage and a mass lesion was responsible.

They undertook a study on 68 children over a period of three years. Age ranged from 11 months to 13 years with the largest proportion between five and seven years. They all fell into the category of minor head trauma. The mechanism of injury did not they said, suggest violent force having been applied, though it was noted that a third had fallen from a height. There was documentation of the site of injury to the head, 26 occipital, 16 frontal, 12 temporal and eight parietal.

After observations and investigations the results were reported. Vomiting occurred anything from 5-10 minutes to an hour after the injury. Half of the children were pale and sleepy. Ketonuria developed in 63% and was most frequent in those who had vomited five or more times. There was no alteration of electrolytes or glucose levels in the blood. In all other respects the children were comparable to those without ketonuria. Skull fractures were no more frequently associated than in those without fracture.

The authors reviewed the literature and the theories presented to explain such vomiting after minor head injury in childhood. This included:

Cerebral oedema.

The speed of onset makes diffuse cerebral oedema and raised intracranial pressure unlikely.

Spreading depression syndrome

This condition involves convulsions and neurological signs and ketosis had not been reported in association.

Cerebral concussion syndrome

This condition may be inappropriately named Clearly the minor nature of the injury is not associated with disturbance of conscious level coinciding with the symptoms. This theory was advanced by Schniktner(1949) who had postulated that cerebral oedema caused in the area of the mid brain resulted in autonomic nervous system dysfunction. Mazuzawa(1977) rejected Schnikter's theory, claiming that the syndrome would occur immediately not after an interval. This would not necessarily be true if there were biochemical as opposed to anatomical or physical mediators.

Haas et al(1975) has advocated a theory that the condition was induced by vasospasm. This too was rejected by Mazuzawa. There is however evidence of vasospasm and facial pallor and vomiting associated with post-traumatic migraine syndromes and with cortical blindness following head injury. Mazuzawa suggested that autointoxication would explain the condition.

The possibility that trauma inducing "shock", presumably defined as stress at the time of injury produced metabolic disorders including disturbances of glucose and fat metabolism. This was associated with the condition seen in cyclical vomiting in childhood where ketonaemia and metabolic acidosis occurred.

The development of ketosis is related to a number of other conditions, diabetes, starvation, dehydration and acetonaemic vomiting. Only the last can be compared with the post traumatic vomiting syndrome of childhood.

The question remained as to why relatively minor trauma to the head triggered this condition? Experimental work by Ogawa(1965)(Ogawa et al 1972) had identified an area in the hypothalamus which played a role in fat metabolism, via the para sympathetic system. Mazuzawa et al(1977) postulated that trauma to the cortex stimulates disharmony within the limbic system and the hypothalamus, reflecting immaturity and instability of these systems in childhood.

The hypothalamus as the centre for sleep and for vomiting had been identified by Hass et al(1959). Sympathetic functions have been identified in the anterior part of the hypothalamus.

The four clinical features seen in this condition in children can be explained on the basis of the location of stimuli in the hypothalamus, which responds to a traumatic insult.

It does not however explain why similar injuries in children of the same age, do not always produce this effect. Nor does it allow any prediction to assist the emergency doctor. The onset however, normally within an hour of injury, and the alarming presentation of the pale drowsy child, should ensure that these children are admitted, investigated and intracranial mass lesions excluded. The condition may be self limiting, but in some cases where vomiting is repeated intravenous glucose and electrolyte solutions may be required. The condition in the vast majority resolves within 24 hours. Where it does not, further search for intracranial pathology is mandatory.

This condition has been consistently observed since it was described by Pickles(1950) and has no anatomical correlates. Vulnerability of immature areas of the brain may be an explanation, but no commitment is made by these authors to identifying the precise anatomical locations.

6 Diagnostic Imaging

The application of xray techniques to the management of trauma commenced in the last decade of the 19th Century, and was subsequently applied to skeletal trauma and penetrating injury. Technical advances, associated with the development of medical, and particularly hospital services, were matched by the expectations of the public. This resulted in the wide application of radiological techniques. Skull xrays have inevitably featured in this expansion, which has occurred particularly in developed countries internationally. The emergency departments are a major contributor to the xray workload, particularly in the number of skull xray requests. The size of the problem has been highlighted by McLean, Joseph and Rudolph(1984) Jennett and Teasdale(1981) who calculated that 1 million patients attend in the Accident & Emergency Departments in the United Kingdom with head injury each year. 40%-50% are children. Of all the patients 150,000 are admitted, 5,000 transferred to neurosurgical care, 650,000 approximately will have skull xrays.

The Radiologist View

Radiologists complained of the demands on resources for skull xrays which they claimed were:-

1. Routine
2. Statistically unrewarding in terms of the detection of skull fracture.
3. Not influencing management.
4. At times incorrectly interpreted.
5. Requested for medicolegal reasons.

It should be emphasised that the debate related to adult patients. The criteria for requesting skull xrays, their application and effects on treatment in the child were less vigorously pursued by radiologists, but some clinicians expressed views.

The routine use of skull xrays in the United States was criticised. Felson(1974) suggested that xrays were ordered before the doctor examined the patient. Reports from Accident & Emergency Departments in the UK had already shown that routine skull xrays were not a problem, Weston(1978) 30%, Strang, MacMillan and Jennett(1978) 58%, Swann, MacMillan and Jennett(1982) 65%, Gorman(1987) 44% including 40% who were children, Thillainayagam, MacMillan, and Mendelow(1978) 80%. The numbers in this study and reports from other UK Centres disproved the unquestioned utility of skull xrays by casualty officers. Despite this a similar view of routine skull xray was expressed by Eyes and Evans(1978) without evidence even in their own paper. They also suggested that the results of skull xrays did not affect clinical management, yet they confirmed admission and the use of antibiotics in their series.

Despite the claim that the detection of skull fractures did not influence management, radiologists sought by the identification of various features to increase the yield of positive xrays, and reduce the overall requests. Bell and Loop(1971) after an appraisal of a large number of features selected 21 of those which were termed High Yield Lists. In application these proved unsatisfactory and were not to be applied to children. Phillips(1979) modified the High Yield Lists, added unconsciousness, base of skull fracture and clinical evidence of depressed fracture. Despite a reduction in the xray requests, 29% of skull fractures would have been missed. The author dismissed them as of no significance. Phillips criteria were tested by Larsen and Koziol(1979), who reported almost half the fractures in his patients would have gone undetected. These initiatives to reduce the numbers of skull xrays, and or to improve productivity in terms of fractures detected produced further studies. Cordon(1981) criticised retrospective review of the value and use of skull xrays.

He designed a study on the retrospective valuation of high yield criteria. He then applied them prospectively as an adjunct to clinical assessment. Rejecting Phillips(1979) criteria, Cordon selected five.

1. Vomiting twice in patients more than 20 years of age.
2. Decreased level of consciousness.
3. CSF leakage or base of skull fracture clinically.
4. Palpable bony abnormality.
5. Neurological abnormality.

Other factors, to be specified by the emergency room physician.

In the retrospective analysis of 1,366 patients, 746 had skull xrays. A utility of 53%, and therefore already a selected group. Forty fractures had been revealed. If Cordon's five high yield criteria had been applied, only 203 or 15% would have been xrayed, 34 fractures would have been revealed and six would have been missed. The initiation of the study reduced xray requests by half. It was suggested this resulted from confidence in the criteria, and that they were supported by senior doctors. The results of the prospective study revealed 16 fractures, 15 of which fitted the high yield criteria selected by Cordon. One fracture was missed. Statistical significance was claimed (<P.0.001). The author concluded that if no high yield criteria were present the chances were 98.7 against a fracture being present. Decreased level of consciousness was the most sensitive indicator and vomiting the least helpful. Cordon concluded that if one criteria was present the presence of a fracture was estimated at 14%, if two were present, 41% and three, 50%. Cordon's criteria failed to detect a fracture in a child who had fallen from a height. There is no comment as to whether the child was considered to be at risk of complications. In fact Cordon quoting Harwood-Nash and Hudson(1971) thought that such fractures might not require admission to hospital or be of any significance.

It was not apparently practice in his hospital to admit fractures in asymptomatic patients. He concluded however "the ultimate responsibility in head trauma, lies with the Physician, and that high yield criteria, served only as a measure of statistical probability!" He did however commend the financial savings accruing to the Radiological Service by their application!

Early in the xray debate Felson(1974), claimed that skull xrays were routine, the results almost always normal, the occasional fracture not significant, but perhaps indicative of more severe injury than was suspected He accepted that skull xrays were of value in the detection of depressed fractures. For other patients he suggested what he thought was a rational solution to the problem. The head injured patient, without any history of loss of consciousness or impairment should be given an xray request card to present the next day. He assumed that generally the patient will only return if he develops symptoms. He offered no solution to the patient who did not return because he was incapable of doing so. Despite opinions regarding medicolegal xrays, he did not see a problem with his recommendations. It is easy to understand why emergency physicians in his hospital were unhappy to implement his policy and elsewhere have a different view.

Freed(1989) in an editorial addressed to emergency doctors, commended the implementation of the strategy of the FDA panel(Masters et al 1987) disregarding the scalp injuries in the low risk group who would not be xrayed, and noting that the high risk group would proceed to CT scanning, he claimed that unnecessary radiology would be reduced by 50%.

DeSmet, Fryback and Thornbury(1979) tested Bell and Loops(1971) high yield criteria in 594 patients and found 17 fractures. Six of the fractures occurred in children, who had none of the high yield criteria. The children were asymptomatic, but the authors concluded that the criteria were not satisfactory in deciding which children should have skull xrays.

In the United Kingdom the Royal College of Radiologists(1981) formulated Guidelines for skull radiography and distributed them to the junior staff with prior teaching. The requests for skull xrays fell by 51% and there was no increase in the number of patients admitted for observation. No patient was reported as coming to harm as a result of not being xrayed. Room for improved compliance was noted, and it was suggested that the initial utility could be reduced to 15-25%.

Medicolegal anxieties were dismissed, claiming that the eminence of the Royal College and the support of the Accident & Emergency Consultants reassured junior doctors applying discretion. The authors accepted that sustaining the reduction might be difficult. The initial Guidelines(1981) were not designed for children.

Masters(1980) undertook a retrospective review of 1,845 patients and claimed that skull films were not effective contributors to the evaluation management or outcome of intracranial injury. He identified high yield clinical criteria for predicting patients at risk of significant intracranial sequelae, and recommended not skull xray but CT scanning as the primary non invasive diagnostic procedure of choice. He expressed the view that for a select sub group of patients skull fracture actually protected the patient against significant intracranial sequelae! Masters subsequently chaired a Multi Disciplinary Group(1987) of Specialists who identified a management strategy where patients were allocated to high and low risk groups. The high risk group proceeded to CT scanning. The low risk group had minimal injury, but it included scalp lacerations and scalp haematomas. There remained between the two a medium risk group where skull fracture might be present, and xrays could be requested at the discretion of the physician.

The authors claimed that patients in the low risk group did not justify skull xray, but careful observation. It is not clear whether this is intended to be at home or in hospital. The exclusion of scalp lacerations might result in depressed fracture being missed if these criteria were used. Scalp laceration is a marker of linear fracture in some children.

There was a concession made for children. The authors acknowledged that children differed from adults in response to head trauma, particularly in infancy and below eight years of age. They were consigned to the medium risk group and not to the low risk category. This allowed the emergency doctor freedom to utilise skull x-rays fairly liberally in childhood.

Thorbury et al(1984) commented on the FDA report stating that no case of intracranial injury or complicated skull fracture occurred in the low risk group. He thought that the recommendations of the panel had medicolegal value and could be used to protect practitioners in litigation. This latter review implied that, perhaps, there would be occasions in which the strategy failed. Subsequent cases of intracranial injury in the low risk group were reported. Thornbury answered the criticisms relating to this failure, by suggesting that all the patients should have been allocated to the medium risk category, placing the responsibility on the emergency doctor.

The Clinicians Case

Clinicians mainly in the United Kingdom were anxious that unnecessary skull xrays should not be taken. They did not disagree with the concept of improving the yield of fractures, particularly as they did not accept that skull fracture did not influence management. Jennett and Miller(1974) had identified the need to detect depressed fractures, particularly those that were open or compound. This was because of the complication of infection associated with such injuries.

They also emphasised the importance of the detection of a skull fracture which alerted the clinician to the risk of an intracranial haematoma developing. Mendelow et al(1983) had calculated the risk of the haematoma in an adult after head injury. With a fracture of the skull and an impairment of cerebral function the risk was 1:4. Fully alert with no fracture the risk was 1:6,000 Skull fracture was clearly identified as a factor in this risk of deterioration. Colleagues had also reported the unfavourable effects of delay in patients with a haematoma reaching neurosurgery It was therefore pertinent that a feature such as a fracture would alert those caring for the patient to the necessity of monitoring progress very closely. Any evidence of deterioration would require urgent action to obtain definitive surgical care and reduce the associated irreversible changes.

It was shown also that patients in coma from the time of injury, could also harbour an intracranial haematoma. The clinician would be alerted to the need for urgent CT scanning and intervention. Seelig et al(1981) had reported improved outcomes when the haematoma associated with severe injury was dealt with early.

Large numbers of patients admitted for observation, and who did not have a skull fracture were utilising resources which it was believed could perhaps more profitable be diverted to those at risk i.e. those with a skull fracture. Excluding a fracture in the otherwise normal patient would allow discharge from hospital with relatively little risk. Patients admitted for strict observations were as a result more likely to receive them.

Although haematomas are associated with a skull fracture in up to 80% of cases, they were only a tiny proportion of those xrayed. Extensive use of xrays to detect a fracture was criticised on financial grounds in the report of the Royal College of Radiologists because it resulted in a poor yield of fractures. Knowing that a fracture was frequently present with a haematoma was not the same as predicting the risk, from a large pool of head injured patients in Accident & Emergency Departments. However it emphasised the value of a fracture in alerting the clinician to the risk.

A consensus view was achieved in the United Kingdom by the formulation of Guidelines by a Group of Neurosurgeons(Briggs et al 1984). These provided advice on the request for skull xrays, admission to hospital, for consultation with a Neurosurgeon and for transfer to Neurosurgery. In addition the Royal College of Radiologist's(1983) had issued their Guidelines, initially for adults only. In their most recent edition, children have been included. Clinicians have continued however to seek to formulate safe guidelines for children.

It is in fact the doctor in the Emergency Department who has the responsibility of matching any guidelines to the patient. Audit has shown deficiencies in this system. Gorman(1986) published an analysis of 12,395 Accident & Emergency Department attendees, 40% of whom were children though he was assessing the value of criteria for admission, he provided information on the value of skull xrays. In his Accident & Emergency Department skull xrays were 44% of head injured patients with the yield of fractures, 3.8% of those xrayed. Compound depressed fractures formed 9.2% of all fractures. Gorman identified the various characteristics amongst all attenders, and those with skull fractures. He concluded however that none of these characteristics were capable of identifying the individual patient who had a base of skull fracture i.e. low sensitivity. The poor performance as a diagnostic test was identified as reflected by their low Youden index. Gorman concluded that it was possible to diagnose skull fracture clinically in only 0.7% of Accident & Emergency attenders. He emphasised that the clinical diagnosis of skull fracture is imprecise, particularly in children. In the majority of British Accident & Emergency Departments this means that the diagnosis is most often made on skull xray. About 40% of Accident & Emergency patients with head injuries do not have skull xray. That establishing the presence or more commonly the absence of a skull fracture is important is demonstrated by the following considerations.

1. 90% of patients who develop an extradural haematoma have a skull fracture on x-ray, and of those without a fracture 90% are less than 30 years old.
2. In a mildly head injured patient the presence of a skull fracture on xray increased by 400 times the likelihood of the development of an intracranial haematoma.
3. In a stroke victim or drunken patient, the presence of a fracture increases by 20 times the likelihood of an intracranial haematoma developing.
4. In a deteriorating patient the presence of a skull fracture on xray may be the only lateralising evidence, or may indicate an unusual site e.g. posterior fossa for an intracranial haematoma.
5. Skull xray may be the only way of diagnosing a depressed fracture and avoiding the complications due to infection, and an intracranial haematoma developing.
6. In a small proportion of patients (10% of whom appear mildly injured) intracranial air may be found, and appropriate treatment instigated so avoiding complications.
7. The presence of a fracture on skull xray may provide one method of selecting patients at risk, for CT scanning.
8. The absence of a fracture on skull xray in the presence of a compatible clinical feature may indicate the diagnosis of white matter shearing and diffuse axonal injury.
9. Exclusion of a fracture by skull xray may allow appropriate pursuit of an alternative diagnosis in a patient with an altered conscious level.

10. Serendipity findings may be apparent, tumour calcification, aneurysm etc.
11. Absence of a fracture in a mildly injured patient may allow that patient to be discharged more safely.
12. Findings such as a sphenoid fluid level or a fracture underlying a laceration indicate that the fracture is compound, and the need for appropriate management to be commenced.
13. Legal problems may be obviated.
14. Skull xray for varied reasons may permit the doctor dealing with the head injured patient to reach a correct decision.
15. Pineal shift may be evident in adults.
16. The presence and site of a radio-opaque foreign body can be determined.

Gorman commented "all attempts by Radiologist to limit skull xrays have shown that using high yield criteria does decrease the number of skull xray examinations and, with varying degrees of accuracy, selects groups of patient more likely to have a fracture". When the statistical significance of fracture in relation to sequelae and complications has been correctly determined from this data the presence of a fracture has proved to be highly significant. Conclusions that demonstrating the presence of a fracture is futile is therefore erroneous. No one criteria is associated with all fractures and even when many criteria are present, the chances of the fracture being present may still be 50% or less. For the clinicians dealing with the patients one at a time, these high yield criteria may be of little value. This is borne out by the degree of non compliance with high yield criteria where these are recommended. This non compliance is not done for spiteful or perverse reasons, but for complex ones. Skull xray and skull fracture are only one aspect of patient management, and not the only consideration. Showing positive findings to be scarce does not justify concluding that such findings are valueless. It would be better for Radiologists to ensure adequate films, correctly interpreted, so allowing Accident & Emergency staff to be more certain in their management of head injured patients (taken from Gorman MD Thesis University of Edinburgh with permission).

Weston(1981) discussed the problem of identifying risk so as to avoid unnecessary admissions of large numbers of low risk patients. Haematomas are much less common in the children who make up half the attenders in Accident & Emergency Departments, but only 1:10 of patients who develop a haematoma. He emphasised that it was the history of amnesia with full recovery that was the best indicator of the potential for developing intracranial haematoma, particularly if a skull fracture was present and acknowledged(Mendelow et al 1982). He commented on the Guidelines issued by a Group of Neurosurgeons(1984) which allowed patients in whom a fracture had been excluded, whose condition was otherwise satisfactory and who were fully conscious to be sent home. He noted that admissions had been cut by

50% by this strategy. The advice of Potter(1974) was emphasised. It was prediction of complication after head injury rather than its confirmation in the form of severe intracranial damage that is of the greatest concern to the A&E Clinician. Jennett and MacPherson(1990) believed that xray will continue for some time in the United Kingdom to be an important component of Triage for mildly head injured patients. They emphasised the value of training doctors in Accident & Emergency Departments in the use and interpretation of skull xrays and the management of head injured victims.

In reports on head injured patients which have followed the implementation of various strategies to reduce skull xrays and increase the yield of fractures the statistical association of skull fracture and intracranial complications have been looked at more critically. The majority have been based on adult studies. Jennett and MacPherson(1990) views that the presence of a skull fracture warrants hospital admission, even though the patient is alert in the Accident & Emergency Department or Emergency Room is based on evidence that if a complication develops a fracture is usually present. Edna(1983) has reported that in patients with a fracture there is a marked increase in intracranial haematoma 10% as opposed to 0.3%. Galbraith and Smith(1976) found that in a series of 307 intracranial haematomas, only 57 did not have a skull fracture and those patients who did not, had symptoms and signs which would have necessitated their admission. A skull fracture in these patients was not required as a predictor, the evidence was present. This is a point which the Glasgow Neurosurgeons have always emphasised. It was not always acknowledged in the arguments which attended the xray debate. The review of a large series confirmed a very significant association between skull fracture and intracranial injury, including 70% of all haematomas and 87% of extradural haematomas(Jennett et al 1977). The latter is the most amenable to treatment, and one where delay will most unfavourably affect outcome, which might otherwise be extremely good.

Feuerman et al (1988) had claimed that skull fracture did not influence clinical management. As 90% of his patients had been admitted, because of impaired levels of consciousness the predictive value did not really arise.

Cooper and Ho(1983) claimed that skull xray and the detection of a fracture was not relevant to management. This view was based on a retrospective analysis of 207 patients, which documented abnormalities which would have justified admission anyway. In 16 who were fully conscious and alert it is suggested that the exclusion of a fracture would have allowed discharge home presumably when there were other indications for admission. These authors claim that more than 90% of patients who had a haematoma have impaired consciousness at the time of presentation. This seems to suggest patients are being seen later in the evolution of their condition than is the case in the Accident & Emergency Department. Past publications had suggested, that haematoma in children occurred more frequently in the absence of a fracture.

Skull Xrays in the Paediatric Age Group

The claims of excessive and unnecessary skull radiology, did not spare the paediatric population. Children often sustained head injuries, in most cases of a minor nature. The same arguments were extended by radiologists to children; too many requests with poor statistical returns of fractures. Similarly it was claimed that the identification of a fracture did not influence clinical management, and that many with fractures had no intracranial abnormality, and many with severe intracranial injury had no fractures.

Early in the debate Burkinshaw(1960) following an examination of 238 children, all of whom had been admitted, claimed that skull fracture did not influence clinical management, except when a depressed or open fracture was detected. He argued therefore that the detection of a skull fracture:

1. Did not alter treatment.
2. Did not give any more reliable guidance than clinical assessment of complications.
3. Did not provide more guidance on the risk and prediction of complications.

He argued "if it could be shown that the absence of a fracture made admission unnecessary, that in itself would fully justify the taking of a skull xray". Subsequently Mendelow et al(1983) and Teasdale et al(1990)· in fact did show that in certain circumstances the exclusion of a fracture allowed the patient to be discharged home without undue risk. Burkinshaw did not consider the identification of a skull fracture as of any predictive value in his patients. However it must be noted that they were all admitted anyway, and the features suggest that many of them had quite minor injuries.

The respected views of Harwood-Nash, Hendrick and Hudson(1971) and Hendrick, Harwood-Nash and Hudson(1964) that skull fracture did not alter management were also based on a large population of children who had already been admitted to hospital. Despite their opinion, which was widely accepted, they admitted to xraying 90% of the children within 24 hours. Boulis, Dick and Barnes(1978) reviewed 1,032 children with head injuries. All were out patients, presumably comparable to an emergency facility? 1,000 were xrayed but criteria were not given. 13% were admitted. It was suggested that skull x-rays were almost routine, and that most were unnecessary. The incidence of fracture in their series was 2.1%. A total of 21 fractures were detected, and in 11 of the children there was no evidence of injury to the head. This makes one question how else would these fractures have been diagnosed. Boulis and his colleagues concluded the presence or absence of a fracture seldom affects treatment, but continued "that it is a valuable sign for identifying:

1. Complications such as intracranial haematoma.
2. Locating haematomas in the posterior fossa, by the identification of a related occipital fracture.
3. Identifying fractures associated with dural tears and the risk of intracranial infection.
4. Visualising intracranial air.
5. Recognising temporal fractures with the associated risk of a 7th nerve palsy, and offering timely treatment.
6. Identifying compound depressed fractures requiring surgical treatment and antibiotics."

Boulis expressed the view that the indications for selected skull xray are inexact and ill defined. He suggested they should be taken only in the presence of:

Coma

Unconsciousness or drowsiness.

In both of these conditions now CT scanning would be indicated.

Lacerations.

This last he concedes would result in at least 40% of the patients in his series having an xray. As scalp laceration is frequent in head injury in childhood this would not contribute substantially to an effective reduction of radiography.

Medicolegal

He quotes the unsubstantiated claims of Evans(1977), that as many as 44% of all xray requests from a casualty department are made for medicolegal reasons. He decided that the categories of medicolegal xray should include road traffic accidents and assaults. In so doing he clearly indicates an acceptance of the value of skull xray to the patient pursuing litigation against a third party. He continues "if no medical considerations exist to justify skull xrays, then no legal considerations exist".

Location of Suspected Foreign Body

Xrays often reveal foreign bodies, which were not previously suspected on clinical grounds, particularly in children. Location and subsequent removal can be confirmed.

Rhinorrhoea and Otorrhoea

Requiring special views of the skull base - to confirm a clinical diagnosis, and are probably not justified, and justified C T scanning.

Positive Neurological Findings.

In the last two situations C T scanning is indicated -

Boulis then suggests that patients not qualifying for skull xrays should be given head injury instructions, recalled and examined the following day! He makes no mention of the cost of this in financial or manpower terms, in comparison with the cost of a skull series. He continues, "those who develop significant symptoms or signs should be xrayed after this 24 hour delay, after which, he indicates they may have to be admitted." If this procedure was followed in his own series of 1,000 patients he does not tell us what the results would be in terms of possible complication or patient satisfaction. Applying the criteria retrospectively to his patients the xray usage would have been reduced to 360 patients who qualified by drowsiness, scalp laceration and medicolegal reasons. This represented an xray utility of 34.8%. He quantifies the financial benefits to the Xray Department, but does not indicate the cost in clinical terms of bringing the patients back for review nor does he report the number of xrays taken following this 24 hour delay. This suggestion would be impracticable and extremely costly in clinical time and patient convenience and welfare. It also extends the period of anxiety, and result in delays.

Leonidis et al (1982) reviewed the records of 354 infants and children and found that the detection of a skull fracture only once altered management, when a depressed fracture was elevated. Profiles were collected for 477 children who had attended in the Emergency Room with and without skull fractures. The groups were compared and analysed statistically to provide a likelihood ratio for the presence of a fracture with each clinical feature. 354 had skull xrays. On the basis of their analysis 13 criteria for skull xray were suggested, if the only intention was to detect fractures. Leonardis et al, observed that fractures are more common among children who develop serious intracranial complications, but they said that they were poor predictors of that pathology. He recommended skull xray for children as follows:

1. Age under 1 years
2. Penetration or foreign body
3. Previous neurosurgery with a shunt
4. Scalp haematoma
5. Skull depression
6. Clinical signs of base of skull fracture
7. Coma and impaired consciousness
8. Focal neurological signs.

Leonidis identified poor interpretation of skull xrays in the Emergency Room with two false positives resulting in admission. Presumably in his hospital skull fracture was used to triage patients for admission? He found a statistically significant risk of fracture for infants compared with old children, but did not calculate the risk of intracranial injury.

Ferry(1982) had complained of the excess use of skull xrays stating they played no appreciable role in the evaluation and management of acute cerebral injury. She emphasised the possibility of a negative skull xray providing a false sense of security. Having considered the role of skull xrays Ferry concluded that already there was an excessive demand for CT scanning in the Emergency Department, and that this was a major dilemma. She laid the responsibility for the child's management firmly with the emergency physician. She suggested that the child be observed for several hours in the Emergency Department. The resources required for such close observation, and the effects of such a policy on a busy Accident Service makes this suggestion generally impracticable. The financial implications for such a service would greatly outweigh the cost of skull radiology. This represents an example of transferring radiology costs to a clinical service.

Garniak et al(1986), writing from Tel Aviv, following the publication of high yield lists analysed 1,000 skull examinations, one third under the age of 15 years. 18 fractures were detected, 13 in children under the age of nine years. Eight of the 13 were infants. All fulfilled the guidelines for xray. 14 linear and four depressed fractures were revealed, eight were parietal, four temporal and four occipital. In only one case was there correlation with a subsequent complication. 12 of the 18 patients were admitted and six were discharged. The admission policies in this hospital were not defined. One of the patients with a fracture had a related intracranial haematoma. The effects on treatment resulted in the elevation of two depressed fractures and interventions for two haematomas. The results of this paper were extremely difficult to evaluate because of inadequate information. It is not known how many attendances in the Accident Department occurred during the study or what happened to those who were not xrayed.

This paper was interesting however in that Garniak et al(1986) had identified a particular category at risk. This was a male child in the first decade of life in whom association was noted between a skull fracture and extradural haematoma.

Piertzak, Jagoda and Brown(1991) commented on the problems of comparing various studies, because of the mix of clinical findings and ages. They suggested a history of loss of consciousness greater than five minutes, decreased conscious level, focal neurological signs, penetrating injury or signs of a fractured base of skull as indicators for xray. Depressed fracture also required radiological evaluation. The finding of a fracture warranted CT scanning and admission. He suggested linear fractures were poor predictors of intracranial injuries. He suggested a low risk group which included scalp haematoma, laceration, contusion and abrasion, who could be sent home in the absence of any high risk criteria. This is the group in which this Study has identified the risk of skull fracture, including depressed fracture. Piertzak made a clear exception to children under two years of age, for whom adult guidelines and criteria were in his view unacceptable. He observed that in these children the Glasgow Coma Score was inapplicable also.

The childhood complications of fracture, particularly in the parietal region were noted. Depressed fracture obscured by a scalp haematoma, which the author had incidentally consigned to a no xray category, was noted as requiring careful evaluation. Piertzak and his colleagues concluded that the controversy continues. "It is very difficult to conclude which child with minor head injury requires neuro-imaging. Available studies do indicate that the emergency physician must have a high index of suspicion and a low threshold for radiographic studies in the paediatric age group." Haywood(1987) endorsed this view.

The importance of skull fracture in childhood, particularly at the parietal site was emphasised by Bonadio, Smith and Hillman(1989). Clinical features were evaluated for predictive value for intracranial injury on CT scanning. One hundred and thirty four fractures of the parietal skull were analysed. There was a male dominance of more than 2:1. All children were admitted because of the skull fracture - 98 had CT scans. 47 children had intracranial abnormalities including 17 haematomas, 11 subdural haematomas. Cerebral swelling was present in 10, subarrachnoid haemorrhage in 10.

In 44 children at least one of the following was recorded: loss of consciousness, neurological deficit or seizure. The predictive value of these features was significant. Parietal skull fracture accounts for 50% of skull fractures in childhood according to Hendrick(1964). Extradural haematomas are eminently treatable, but initially may have minimal symptoms or physical signs. This period often coincided with assessment in the Emergency Department. The potential may go unrecognised and consequently delay results. Rivara et al(1987) had attempted to evaluate clinical features to produce high yield criteria for CT scanning.

In Bonadio's(1989) report there was a high incidence of morbidity in head trauma associated with parietal skull fracture in ages ranging from 2-12 years. The association of altered level of consciousness was six times more likely to be found with intracranial abnormality, than if this feature was absent. Seizure activity was also predicted. By contrast 50% with a skull fracture, and no symptoms had normal CT scans. These fractures were usually linear. The number of depressed fractures in this report might have been of relevance to the incidence of seizures. Bonadio(1989) compared the incidence of haematoma in their series of parietal skull fracture with other reports of fractures at all sites and of all types. They found the incidence of epidural haematoma with fractures to be 10% as opposed to epidural bleeding only 1% without fracture. Subdural haematoma associated with fracture

8%, as opposed to 3%. The subdural haematomas were under one year and in the older group of more seriously injured children. The 71% of children with extradural haematomas were all over two years of age.

The authors concluded, children with parietal skull fracture are at a significant risk of intracranial injury. They stated that any neurological impairment associated with parietal skull fracture is an indication for urgent CT scan and neurological assessment. The authors provide no information on children admitted during the same seven year period without skull fracture, but with similar intracranial pathology on CT scanning.

Chan et al(1990) undertook a retrospective multivariate analysis of more than 12,000 young patients in order to identify risk factors in paediatric head injury - 159 had intracranial complications - 132 haematomas and 27 diffuse swelling. The statistical analysis identified two factors with a predictive value for the primary emergency physician. One was impaired conscious level, the other skull fracture. Together these produce a 75% risk. Skull fracture alone carried a 2% risk. Impaired consciousness had an intermediate level of risk at 19%. Skull fracture alone was age dependent.

The authors commenting that children are not a homogenous group - analysed the relation of skull fracture to age and intracranial haematoma.

In children under two years the risk was 1:50, 2-6 years 1:15, 7-10 years 1:6, 11-15 years 1:3. In 4871 infants and toddlers, with linear fractures there were no haematomas. Chan claimed that skull fracture as a guide in the prediction of post traumatic intracranial haematoma is significant and highly age dependent. Routine skull xrays were recommended for children over two years with admission for observation when positive. Where there is no loss or impairment of consciousness and/or a skull fracture the risk is negligible. The condition, which may still generate anxiety, is post-traumatic swelling - which can develop in asymptomatic children. There is as yet no predictor of this condition. Chan et al(1990) referred to the necessity for correct interpretation of skull xrays when taken. A child with a posterior fossa extradural haematoma, had inadequate skull examination and a fracture was missed, in their series, with serious outcome.

In Chan's report if the two identified features were excluded, admission would have been needed by 6781 patients and covered 97% of the abnormalities. The admission rate would have been reduced by 56%. Godano et al(1992) and his colleagues reported on 62 children aged 1-6 years who were treated following minor head injury 33, more than 50%, had lesions of surgical interest - 17 had extradural haematomas, seven contusions, four depressed fractures and three depressed fractures with underlying cerebral injury. A skull fracture was found in 88% with a cerebral lesion. 15 children required surgery.

The authors found no correlation between age and Glasgow Coma Score and complications. Only skull fracture was significantly associated with intracranial pathology. Godano et al(1992) on the basis of this analysis withdrew their previously published belief, that there was no significant relationship with skull fracture. They quoted the report of Teasdale et al(1990) and recommended the use of skull xrays in head injured children and CT scans, where a fracture was detected. This report emanated from a neurosurgical unit. Admission policies were presumably selective, though criteria for admission are not given. The children were however defined as minor GCS 13-15 yet 2% required surgery. The fracture alerted clinicians to the need for CT Scanning. This may allow much earlier detection of treatable lesions, reduce delay to transfer and avoid deterioration. These authors as a result of this work, withdrew their earlier opinion that skull fracture was not significant in relation to intracranial lesions of surgical interest(Servedei, Galassi and Calbucci 1992).

Skull Fractures in Children

Skull fractures are classified according to their location, and characteristics. Linear fractures are seen in the skull vault, and many are simple, closed and not always associated with any evidence of underlying cerebral trauma. More severe injury may produce multiple fractures with primary brain injury. Fractures carry the risk intracranial complications.

Linear Fractures

Linear fractures of the vault of the skull are the commonest. They are more frequent in infancy, because of the fragility of the bone, and in this age group may rarely be associated with two complications, unique to the youngest children.

Subepicranial hygroma(Dyke 1937) occurs when the fracture extends into a suture line, with laceration of the dura. Cerebrospinal fluid dissects beneath the periostium. The condition is normally self limited, if alarming to the carer.

The second complication is the growing fracture(Kingsley, Till and Hoare 1978; Tandon, Banerji and Bhatia 1987), which manifests some time after usually severe injury. There is laceration of the dura, and herniation of cerebral tissue. The bone edges cannot heal and radiologically are widened. The condition presents as a pulsating mass requiring neurosurgical intervention. There is usually a neurological deficit.

The risk of these conditions, in addition to others, justifies a liberal use of skull xrays in infancy.

Depressed Fracture

When forces are applied to a small localised area of the skull, depression may occur, involving the full thickness of the bone, which may be driven inwards, a distance greater than the thickness of the bone. There may be comminution, and the fragments may penetrate the dura, and the underlying brain tissue may be damaged. Haemorrhage and contusion may result. As the agent causing the depressed fracture frequently breaches the scalp, the wound is open and carries the risk of infection, and possibly epilepsy(Jennett 1975; Hendrick and Harris 1968) in the future.

Depressed fractures are defined as those in which the inner table of the skull is depressed by at least the thickness of the skull itself. Depressed fractures are compound if associated with an open wound of the scalp whether or not the dura is breached. Penetrating depressed fractures are those in which the dura is also lacerated or incised.

In a series of depressed fractures from three centres, Oxford, Rotterdam and Glasgow involving 1,000 patients reported by Brackman and Jennett, various features were studied. The mechanisms were Road Traffic Accident, industrial injury, assaults and accidents at home and in sport. In adults the assault accounted for 15%. Half of the total patients were under the age of 16 years. In this group, falls, sport and play accounting for those not due to Road Traffic Accident. Assault was rare in childhood.

The younger children in the series sustained injury of a penetrating nature against sharp objects usually at play. In half of the cases no history of loss of consciousness was recorded. Focal signs were present in only 20% and half of the compound fractures had dural tears. Brain damage may be considerable under the depressed fracture site but is less so in children, than adults.

Depressed fractures are not infrequently overlooked in the initial medical assessment. Some may not even seek medical help until the symptoms of a complication ensue, usually infection or a fit. In the A & E Department scalp lacerations are common, occurring in 40% of the head injury attenders in the Scottish Hospital Head Injury Study, 62% Swann et al from an Inner City Teaching Hospital(1981)

The features of the wound when CSF or brain tissue are visible are easy to recognise. Palpable depression and fragmentation is the exception. Fractures associated with scalp swelling particularly, and cephal haematoma with underlying linear fracture are frequently misinterpreted as being depressed, especially in infants. Loss of integrity of the galea should heighten suspicion of an underlying fracture In the absence of clinical evidence, the mechanism and cause of injury may be the only factor to arouse suspicion, and lead to appropriate x-ray examination. Standard views may be unhelpful, and suspicion should prompt the examining Medical

Officer to request the appropriate views to ensure that depressed fracture is not overlooked. Two films taken at right angles at the site of injury, or tangential views are the most helpful in this context.

The early and accurate diagnosis of depressed fracture is important because of the complications which can ensue. If the appropriate management is instituted early, recovery from non missile injury producing depressed fracture, is usually rapid and complete. However in a quarter of cases, complications occur including infection, intracranial haematoma and damage to the venous sinuses. Of 359 patients with compound depressed fractures referred to a Neurosurgical Unit, 38 developed infection giving an overall rate of 10.6%. In 62.0% of these the established infection was intracranial with abscess, meningitis or both. Of 15 patients in this category four died. The morbidity of infection included central nervous system damage, and later post traumatic epilepsy.

The primary treatment of the injury had been inadequate in nearly all of the 24 patients with established infection. In 62% a fracture was not suspected, the injury being regarded as a simple scalp wound. In five the fracture was recognised, but the treatment was inadequate. A history of loss of consciousness, of brief duration only, was recorded in 71% of patients. In the majority of infected patients in this series the infection was established within one week of the injury. The incidence was significantly greater in those patients in whom there had been a delay of more than 48 hours between injury and definitive treatment. 53% of the patients in whom the diagnosis of compound depressed fracture was missed, were actually sent home from the Accident & Emergency Department immediately after their injury. Of 28 patients attending Hospital soon after injury 68% either had no skull films taken, or if they did the fracture was not reported in time to influence primary treatment. In eight of the patients major complications had developed before the fractures were recognised. By this time 53% of the patients had neurological symptoms or signs. Whilst some of the compound depressed fractures might have been diagnosed by adequate wound exploration, it was evident from this series that a significant number of patients were not xrayed. It was suggested that mortality and morbidity might well have been reduced by an index of suspicion, good quality films, suitably interpreted, together with early surgical debridement in an appropriate neurosurgical setting. The role of antibiotics in the prevention of infection, i.e. the primary treatment in the Accident & Emergency Department, is an adjunct to surgical wound management. Lessons learned at time of war, Cushing 1918 and again in the Vietnam and Korean conflicts showed that prescribing of antibiotics was no substitute for adequate early and effective surgical debridement of the wound.

The recommendations arising from the first paper were implemented. The report of a further 216 compound depressed fractures of the skull seen between 1974 and

1978 showed a gratifying reduction of infection. Of five cases reported in the series, one did not have a skull xray, and in a second an xray taken, failed to identify the fracture. The rarity of signs and symptoms of cerebral injury at the time of the accident or on presentation in the A&E Department may result in the patient, with a compound depressed fracture, being regarded as a minor or trivial injury. Exploration of the wound and the consideration of the mechanism of injury may arouse suspicion. It is essential in these patients to undertake the appropriate radiological investigation. The correct diagnosis will result in treatment in the form of penicillin or erythromycin, together with tetanus prophylaxis. Suspicion of contamination with other organisms, eg Clostridium should prompt appropriate selection of a broad spectrum antibiotic. Referral to the Neurosurgical Unit for debridement can then be made.

The incidence of depressed fracture has been estimated at 3.4/100.000 - 75% not clinically suffering serious head injury. Xrays are essential to diagnosis, with secondary C T scanning.

Decisions in the Accident & Emergency Department relating to depressed fractures have traditionally been to seek the advice of a neurosurgeon, and this should continue. Availability of CT scanning at the base hospital would, however, allow the identification of underlying brain injury, contusion or haematoma prior to discussion if the patient's condition was otherwise stable. When there is no evidence of intracranial complication and no wound, transfer to neurosurgery may not be required, though advice should be sought and followed.

Depressed fractures complicated by an external wound, fragmentation of the bone, foreign material or dural tearing require neurosurgical care. CT scan will then normally be undertaken in the specialist centre.

The responsibility of the Accident & Emergency doctor lies in the confirmation of the depressed fracture by skull xray including tangential views. Control of any bleeding should be achieved, preferably by the application of simple sterile dressing, gentle even pressure and the institution of antibiotic therapy and tetanus prophylaxis as appropriate.

The management of simple depressed skull fractures in childhood, that is those not associated with a wound, was discussed by Steinbok et al(1987). It was suggested that the previous treatment - surgical elevation of simple depressed fractures had little clinical justification. The authors examined the condition of 111 patients, all under the age of 16 years. A retrospective review examined skull features with the depth of the depression in millimetres, CT scan findings, and the presence or absence of a dural laceration. Follow up data was obtained for epilepsy, neurological status and the cosmetic result. It was tested statistically. The result showed that simple depressed fracture occurred in younger children. The aetiology was different and the impact less forceful. Seven children from 56 with simple fracture had neurological dysfunction. Only four out of 36 of the simple depression had dural tears.

The patient with compound depressed fracture had a much higher incidence of dural laceration and carried the risk of infection.

The author suggested that the management of compound depressed fractures had clouded the treatment of simple depressed fracture in the past.

A review of 274 patients admitted to a Neurosurgical Unit in Dublin, emphasised that of a total number of children admitted under the age of 11 years, 85% were fully conscious or drowsy only, yet 20% of these children required neurosurgery. This emphasises again the fact that depressed fracture can occur in children without impairment or loss of consciousness at any stage. Only skull xray may reveal a fracture, in a fully conscious child, which carries a high risk of complication and which may otherwise be missed.

Base of Skull Fracture

Five bones form the base of the skull, the cribriform plate of the ethmoid bone, the orbital plate of the frontal bone, the sphenoid, the petrous and squamous portion of the temporal bone, and the occipital bone. Fracture results generally from the application of moderate or severe force. The incidence was reported by Einhorn and Mizrahi(1978) as 3.5% in 1,300 paediatric patients. It is possible that the incidence is underestimated, because of the difficulty in confirming the fracture radiologically.

The clinical signs depend on the location of the fracture in the anterior, middle or posterior cranial fossa. Anterior fossa fractures are associated with periorbital and conjunctival haemorrhage, anosmia and cerebrospinal fluid leakage from the nose. Fractures of the middle fossa are associated with retro auricular bruising, Battles sign, haemotympanum, cerebrospinal fluid discharge, and bleeding from the ear, and varying degrees of disturbance of the 7th and 8th nerve, auditory ossicles, and vestibular dysfunction(Waldron and Hurley 1988; Nicol and Johnstone 1994). The clinical features are those of impaired hearing and disturbances of balance, with or without tinnitus.

Fracture of the posterior fossa may be associated with evidence of injury to the structures within the area, with or without haemorrhage, or haematoma.

Severe degrees of base of skull fractures associated with injury to the intracranial contents, may be manifested by coma from the outset, and widespread cerebral dysfunction, including evidence of injury to the cranial nerves.

The management of base of skull fracture commences in the Accident & Emergency Department. The diagnosis made on clinical grounds, but fractures may be demonstrable if the basal fracture extends into the vault, or if intracranial air is present. Fractures may be diagnosed by tomographic views of the base. However, this is a difficult procedure, and is dangerous in the presence of risk of cervical spine injury. CT scans may demonstrate base of skull fractures, providing the appropriate technical facilities are used.

The clinical features may be associated with a cerebrospinal fluid leak, from the nose-rhinnhorrhoea or from the ear-otorrhoea. Some children may not have evidence of cerebrospinal fluid leakage even though the dura may be torn. It is important to remember that if the patient is lying flat, following admission, the cerebrospinal fluid may trickle down the back of the nose and may not be apparent. When it is safe to do so, the child may be examined in an upright, or forward flexed position. Gross swelling around the nose may prevent the free flow of CSF to the exterior, the fluid being swallowed via the pharynx. If a fluid discharge is available it can be subjected to testing for dextrose. Dextrostix are not suitable and give false results(Steedman and Gordon 1987). A specimen of the fluid discharge should be obtained and sent to the laboratory for glucose estimations.

The decision to use prophylactic antibiotics is now somewhat controversial. It was common practice in the past. It is recommended by Brawley and Kelly(1967) to prevent organisms in the upper respiratory tract gaining access to the subarrachnoid space. Others, Einhorn and Mizrahi(1978), have withheld antibiotic prophylaxis, and claim that there were no complications in their 46 patients in a controlled trial.

Ignalzi and Vander Ark(1975) undertook a prospective study. No infection occurred in children without antibiotics. There were adverse affects in 54 children who were given prophylactic antibiotics; two developed meningitis. The problem of antibiotic resistance or the overgrowth of alternative organisms is a risk, which was noted.

In a prospective trial Hoff et al(1976) used a three level dosage strategy, and found that there was no evidence of infection in either of the three groups, one of which included no antibiotics.

Cooper(Head Injury 3rd Edition 1993) has indicated that in his Unit antibiotic prophylaxis is not given, during the period of initial observation. He has warned of the risk of suppressing the normal bacterial flora in the nasopharynx, with resulting problems of bacterial resistance and overgrowth with gram negative organisms.

Base of skull fracture with dural tearing can occur in the absence of CSF leakage. In these cases it may be possible to confirm the fracture by the use of skull xrays with the patient in the brow-up position where air will be seen within the skull. Air fluid levels may also be demonstrable.

Virtually all patients with a diagnosis of base of skull fracture are likely to be admitted to hospital. They require close observation and failure to improve with lethargy may be indicative of the onset of intracranial infection.

If CSF fistula persists in either the anterior or middle fossa, neurosurgical advice should be taken, and the options for neurosurgical intervention decided by the specialist team.

A CT brain scan should be undertaken early in the patient's management to exclude the possibility of the development of a mass lesion, and to assess the brain damage associated with the primary impact.

The bacteria associated with CSF fistula may be different in children than in adults. In both the commonest infecting organism is the streptococcus pneumoniae. In children there is a higher incidence of infection from haemophilus influenzae. This may be because the child is more likely to be harbouring the organism in association with infections of the middle ear, or upper respiratory tract. The Report of a recent Working Party on antibiotic prophylaxis, was unable to confirm beneficial effects in trauma, leaving the matter open for future research.

CT Scanning and Paediatric Head Injury

When the data in this Thesis was collected CT scanners were available in only three of the participating hospitals, and were restricted to social hours usage, with limiting protocols. All the 155 children who were subject to scanning were transferred to the related neurosurgical service, not only for their investigations, but for neurosurgical care. Since the Study scanners have been made more widely available, in District General Hospitals., Even now the scanners may operate only in normal hours, when there are competing demands from conditions other than trauma. Head injuries frequently present out of hours.

At the present time however, this Thesis would be incomplete, if the investigative benefits of CT scanning emanating particularly from the United States of America were not reviewed. In the immediate future there will be increasing numbers of scans, and ultimately the situation as practised in North America with 24 hour availability will hopefully become the norm in the UK. There will however be need for modifications in practice, to take account of the fact that there are many more neurosurgeons and scanners in the United States than in the United Kingdom. Similarly there are many more Trauma Centres in North America with all the services available at one site. In the United Kingdom in the foreseeable future neurosurgery will continue to be a regional service. Head injuries, particularly the minor categories are likely to attend in the Accident & Emergency Department, and it is from this group that avoidable complications may arise, and decisions regarding scanning may stimulate controversy, similar to that for skull xrays.

Serious head injuries requiring neurosurgical interventions will still go to Neurosurgical Units, possibly even by advanced transport systems, and may have scans there to avoid delays. The exclusion of surgical lesions, in comatose patients, may avoid precipitate and dangerous transfers from the base hospital and allow more co-ordinated planned management decisions.

Patients with multiple injury may benefit from scans at the base hospital, which exclude neurosurgical lesions, allowing surgery at other anatomical sites to be undertaken. The brain scan should be taken, before contrast is used for the assessment of abdominal injuries. Physicians caring for the patient in ITU can monitor the cerebral pathology. A computerised tomographic scan is the investigation of choice in acute cerebral injury. It can be completed in 15 minutes, and allows peripheral access to the patient to maintain resuscitation. It is also non invasive and painless, an important consideration in children. The immediate delivery of information on intracranial pathology facilitates management planning.

CT can provide information on parenchymal tissue, readily identifies blood, detects compression and shift, swelling and infarction. The use of windows can identify fractures. The following can be demonstrated:

1. Cerebral contusions.
2. Mass lesions.

a) Extradural haematoma)
b) Subdural haematoma) with or without midline shift.
c) Intracerebral haematoma)

3. Shear injuries - diffuse axonal injury (exceptionally as CT scans may initially be normal).
4. Cerebral swelling.
5. Intraventricular bleeding.
6. Subarrachnoid haemorrhage
7. Fractures using special techniques.

MRI scans can complement CT scans and can detect lesions not seen on CT scans. This facility has little practical value in A & E Department assessments at the present time.

The interpretation of CT scans and the diagnostic features of the various entities is beyond the scope of this Thesis. Scans in working hours are normally interpreted by a Radiologist, or may be transmitted electronically to the Neurosurgical Unit. Out of hours local protocols are organised with the Regional Neurosurgical Service.

In the future, if Trauma Centres are established, staff will be available 24 hours. Accident & Emergency Department doctors will require special training in interpretation of CT scans and additional resources will be necessary to ensure competence.

Anticipating the wider availability of CT scanners in District General Hospitals MacPherson, Jennett and Anderson(1990) reviewed the records of 1551 patients, who had been scanned at the Regional Neurosurgical Centre over a five year period.

They found that 90% of scans were done out of hours. 50% revealed a haematoma, 28% contusions, 13% shearing injury and in 9%, swelling. In 22% the examination led to urgent evacuation of a haematoma. Single scans were not adequate for all the patients, 41% required more than one and 10% more than two subsequent scans. In those whose first scan was abnormal a subsequent scan showed a surgical lesion, though no initially normal scan did so. Jennett and MacPherson(1990) warned of the implications of this analysis, if CT scans were to be undertaken in the District General Hospital and of the need for local policies, identifying the patients who should be scanned there. They emphasised

(i) firstly and most importantly, the early diagnosis of the intracranial haematoma, before the signs of deterioration and compression are evident clinically. This depends on the identification of risk factors for intracranial haematoma reported by Mendelow et al(1983) and Teasdale et al(1990).

The presence of impaired conscious level and a skull fracture should alert the physician from the outset of the need for urgent CT scanning. If a haematoma is confirmed, transfer is indicated. Reduction of delays has improved the results of CT scanning. Early detection in A & E Departments would further improve the results of surgery in these cases. Avoidable delays resulting from scanning at the base hospital might paradoxically reduce the speed of access to operation.

(ii) The second objective would be to reduce transfer to the Neurosurgical Unit of those who required only a CT scan. A CT scan at the base hospital might confirm normality and allow an otherwise well patient to be discharged home, reducing the demands for beds for observation and transfers to neurosurgery.

(iii) Thirdly, patients at the base hospital, with impaired consciousness but a normal CT scan could be progressively monitored and reference made to the Neurosurgical Unit as indicated by serial scanning.

In certain circumstances with very severe injury and no neurosurgical lesions, the patient might be retained in an Intensive Care Facility. Alternatively such patients might be transferred to gain access to Neurological Intensive Care for specialised treatment, particularly new initiatives in management, with research development.

Jennett and MacPherson(1990) did not identify children in this report, and did not specifically mention problems of raised intracranial pressure, and cerebral swelling. The identification of pathology in severe and moderate head injury is likely to continue to involve A &E Departments very closely with their neurosurgical colleagues.

In the UK because of limited access and the numbers of scanning units available, much less attention has been given to the evaluation of minor head injury using computerised tomography. Evidence is accumulating in North America that CT scanning in minor head trauma, GCS 13-15 has revealed intracranial pathology and lesions of surgical interest. Many patients of this type in the past were involved in the controversy regarding skull xray, and the need to admit for observation.

There are a number of options.

1. Universal scanning of patients with minor head injury attending in Accident & Emergency Departments.
2. The use of a skull fracture to triage for CT scanning.
3. The role of history of loss of consciousness or unconsciousness at the time of attendance and special considerations for the paediatric age group all being taken into account.

This topic is relevant to the utilisation of scanning and decisions regarding disposal from the Accident & Emergency Department.

The value of a CT scan to the Physician in the moderately or severely injured child has been demonstrated by reports over the last 15 - 20 years.

The benefit to the Physician was demonstrated by Zimmerman et al(1979). He analysed 320 patients, 50% of whom were children, who were subjected to the examination. Patients were allocated to four clinical categories based on the level of disturbance of consciousness. 144 children were available for analysis, males dominated by more than 2:1. The results of examination by Radiologists were reported.

Acute generalised swelling occurred in 46 patients, 36 of whom were under the age of 17 years. Focal cerebral swelling occurred in 12 patients, 75% of whom were children. Focal intracerebral haematomas and haemorrhagic contusions were described. Focal extracerebral abnormality was found, 12.5% of patients had a subdural haematoma. 4.9% had an extradural haematoma. In 13 patients the mass effect was the sole abnormality.

Skull radiography confirmed fracture in 32% of the children and 23% of the adults in whom there was no CT abnormality and 69% of the children and 67% of the adults in whom there were CT abnormalities detected.

The authors discussed in detail the significance of their findings in relation to surgery, management and prognosis.

They identified paediatric patients with bilateral cerebral swelling, as a distinct group, who have a different course and outcome from adults. It was their view that acute generalised swelling in children is a secondary effect. It was suggested that this was due to primary change in the cerebrovascular resistance, triggered by trauma and resulting in increased cerebral blood flow, intraparenchymal vasodilatation, increased cerebral blood volume and reduced cerebral compliance. This produces cerebral swelling, which may lead to oedema or on its own, may produce sufficient mass effect to result in deterioration and death.

Prior to CT no diagnostic method of demonstrating cerebral swelling was available. Early detection and early control of secondary injury are major factors in reducing mortality.

Referring to extradural and acute subdural haematomas Zimmerman and Bilaniuk(1979) observed that with CT the delays in diagnosis are now preventable. In isolated extradural haematomas the mass can be defined and evacuation expedited. The mortality in this series was less than 10% for this condition. Any factors which reduce delay from injury to surgical intervention, and which protect the patient from complication and secondary insults will lead to the "Zero mortality" predicted by Bricolo and Pasut(1984).

The variety of abnormalities demonstrable by computerised tomography has been reported by a number of authors. One series from Massachusetts gave the results of CT scans in 100 cases of head trauma, age is not specified. Merino-de-Villasante and Tavares(1976) used degree and duration of altered consciousness, to correlate with CT findings. They claimed a linear correlation between certain clinical features, and the abnormalities detected on the scans. The authors remarked on the importance of the timing of the scan. Very early scanning might not reveal abnormalities subsequently identified, and the need for sequential examinations was noted. The authors reported CT scan abnormalities in three patients, who were clinically normal, and in whom no skull fracture had been demonstrated. These authors included plain skull xrays with the CT scan to ensure a correct diagnosis in the majority of cases of acute head injury. The exceptions were bilateral subdural haematomas.

Rivara et al(1987) used clinical criteria to correlate with CT findings. In a retrospective study on 98 children aged 2-12 years who received CT scanning for head trauma, the clinical finding of Glasgow Coma Score 12 or less, altered consciousness on admission and focal abnormalities on neurological examination were each significantly associated with abnormal findings on CT scan, and this was found to be statistically significant. A study of a further 51 of the 98 children who had a Glasgow Coma Score greater than 12 also had abnormal CT scans. The findings in the 16 patients with mild head injury resulted in four requiring immediate surgery. The authors emphasised the benefit of detecting operable lesions before deterioration has occurred, citing the work of Bricolo and Pasut(1984) and Seelig et al(1981). Rivara et al(1987) concluded that no clinical findings alone, or in combination, accurately identified all the patients with abnormal CT findings. They also warned against the assumption that the results of studies on CT scans, in predominantly adult populations, may be transferable to the paediatric age group. Prior to Rivara's work Zimmerman and Bilanuik(1981) had reported on computed tomography in the paediatric population. In 262 CT scans performed on children less than 18 years of age, of 40 of the patients with minimal or no disturbance of consciousness, 40% had abnormal CT scans. There was however no correlation to Glasgow Coma Scale or clinical parameters. Rivara(1987) stated that their study, which had not attempted to address the incidence of abnormal CT findings, indicated that the use of CT scans in the initial evaluation of most patients with paediatric head injury, may prevent missed, or delayed diagnosis with benefit to the child.

Clinical predictors of intracranial injury, to assist the casualty officer in the selection of patients for CT scanning, were sought by Hennes et al(1988). They reviewed the records of 55 patients who had undergone a CT scan for head trauma. They classified the severity of head trauma according to four variables:-

1. Altered mental state, as defined as a history of physical findings of unresponsiveness, or an inappropriate motor response to verbal or painful stimuli.
2. Evidence of increased intracranial pressure, defined as the presence of persistent and/or progressive headache and vomiting.
3. Seizure or focal neurological deficit.
4. Scalp and/or facial injury defined as haematoma, contusion and/or laceration.

Injury was considered mild if none of the above is present, moderate if only facial or scalp haematoma, contusion or laceration was present, and severe if one or more of the three variables were noted. The author remarked on the value of the Glasgow Coma Scale, and in children the development of the Raimondi Scoring System(1984) for very young children. The results of their study on 55 patients showed a male dominance, with an age range of 1-15 years, 44 had severe trauma of whom 84% had abnormal CT scans. Six patients with severe head trauma, and abnormal CT scans were described as being alert, orientated, and without neurological deficit at the time of their presentation in the emergency department. All had a Glasgow Coma score of 12 or greater. Three patients in this category had extradural haematomas and two required surgical interventions. Three patients were classified as having moderately severe head injuries and eight had mild head trauma. None of the 11 with mild or moderate head injury had any evidence of brain injury or intracranial bleeding on their brain scans. One patient in the moderate group had a depressed fracture, and two patients in the mild group had a linear fracture. When the CT findings were matched against the clinical features, altered mental status was present in 84%. It was calculated that the presence of altered mental status, and severe head trauma were significantly associated with abnormal CT scans. Hennes comments "high yield criteria for urgent intracranial CT scan both in medical and surgical adult patients are well established. Such criteria are not adequately addressed in the paediatric literature. Hennes asked whether these results suggested that the Glasgow Coma Scale might have limited application in the paediatric population. This question had already been raised by Zimmerman and Bilaniuk(1981) and Rivara et al(1987) . Hennes felt that the additional application of clinical criteria had permitted identification of their patients, with intracranial injuries, that would have been missed if the Glasgow Coma Score had been used as the determinant for not undertaking the scan. The authors suggested that until an accurate prospective study could be undertaken, all children with the features of severe head trauma, should be considered for immediate diagnostic CT scanning. They concluded that the history of the event, and clinical examination were the most accurate predictors for scanning in children with head trauma, regardless of their level of consciousness on the Glasgow Coma Scale. They identified the benefit of obtaining a CT scan, so that a patient might be discharged from the emergency department, after a complete neurological examination. Instructions would be given to return in the event of symptoms. It is interesting to note that in this series, the three epidural haematomas reported, had no history of loss of consciousness, or of seizures, and no neurological deficit in the emergency room. Only headache and vomiting were present, together with a Glasgow Coma Score of 12 or greater. In the absence of information about the cause and mechanism of injury, a reduction in the Glasgow Coma Score seems to have been an effective determinant in selecting these children. Skull xrays were not used to select for CT scanning, and it was not reported whether a fracture was associated with the extradural lesions. Another feature of this report is that only one reading of the Glasgow Coma Score is reported, at the time of examination in the emergency room. No information is provided as to whether that represented a deterioration in conscious level, from the time of the accident. As none of the extradural haematomas had been unconscious at the time of the injury, there was no lucid interval.

Bruce and Schut(1977) discussed the value of CT scan following head injury in children. He warned that brief admission for observation might not be safe, because an expanding mass lesion may not produce symptoms during this initial period. This was in contrast to Sainsbury and Sibert(1984), who had suggested six hour observation was all that was required, as children who were developing complications would have abnormal features at this stage. Bruce and Schut(1977) thought that the indications for scanning in minor injury were difficult to confirm, but stated that scanning is a much more effective way of excluding a haematoma than observation and more cost effective than even half a day admission. He asked whether all admitted children required the scan or only those who had a history of loss of consciousness? He warned of scanning to early when a small haematoma might be missed. He related selection to age. In those under one year he suggested prolonged unconsciousness, full fontanelle, bradycardia and skull fracture crossing suture lines as indicating the need for CT scanning immediately. Children over one

year with focal injury he said should have xrays to rule out a depressed fracture, particularly if there was an open wound. He suggested CT scanning if there was impairment of consciousness, focal neurological deficit or a depressed fracture.
Unconscious children should be scanned urgently. Bruce and Schut then outlined the features of all the lesions demonstrable on CT scanning. They also warned of normal scans in 26% of severely injured children with diffuse axonal injury.
Feuerman et al(1988) in an analysis of 373 patients with minor head injury - Glasgow Coma Score 13-15 found that patients with impaired level of consciousness and a skull fracture, had a significantly greater risk of intracranial haematoma. They claimed however that the detection of the skull fracture did not influence management. Clearly this was because 90% qualified for admission, and CT scanning. These authors were not considering skull fracture in the emergency room, to triage the patients for CT or admission. Harad and Kerstein(1992) reporting from a Level 1 Trauma Centre, where selection may well have influenced the patient group studied, evaluated 1,875 patients and 497 consecutive CT scans. These authors used Glasgow Coma Score, amensia, mechanisms of injury and bedside assessment. The patients were graded by Glasgow Coma Score 13, 14 and 15. CT abnormalities were found in 18% of those with a Glasgow Coma Score of 13 or greater, 17% abnormalities were found with a Glasgow Coma Score of 15, 23% Glasgow Coma Score 14 and 27% Glasgow Coma Score of 13. CT abnormalities were found in 33% of those with a history of loss of consciousness but CT scans were normal in 62% without a loss of consciousness. 11 patients required surgery, six had extradural haematomas, and five of the six had a Glasgow Coma Score of 15. No bedside features predicted CT abnormality.
The authors referred to the views of Klauber et al(1989) on the determinants of head injury mortality and the importance of the low risk patient. Their opinion was that the higher mortality rates were the results of population differences, level of observation and time to CT scan. However the alternative explanation is that the low risk patient has a higher risk of intracranial haematoma, and delay influences outcome.
Harad and Kerstein(1992) concluded that emergency department scans should be performed on all patients previously classified as mild or low risk for intracranial trauma, regardless of the Glasgow Coma Score. If the scans are negative, these patients may be discharged home under supervision. Moran et al(1994) studied the results of CT scanning to avoid admission. 200 cases were studied in an attempt to find predictors of abnormality in CT scans in minor head trauma. The patients were divided into those with a history of loss of consciousness and a Glasgow Coma Score of 13-15, and those with no history of loss of consciousness and Glasgow Coma Score 13-15. CT scans were positive in 4% of all patients and 8.3% of the

scans. In those with a Glasgow Coma Score 13-15 and no history of disturbance of consciousness, all the scans were negative. In those with a Glasgow Coma Score 13-15 with a history of loss of consciousness, eight were abnormal. Nine skull fractures were detected, five associated with abnormal scans. Two patients required neurosurgery, one for a temporal fracture and extradural haematoma, and one for a depressed fracture. Both had a Glasgow Coma Score of 15 and a history of loss of consciousness. The authors concluded on the basis of their findings that loss of consciousness, and skull fracture were independent predictors of positive CT scans, and recommended immediate CT scans in all cases of minor head injury, with loss of consciousness or suspected skull fracture. This would optimise outcome in those needing surgical intervention, and avoids delays. In their view patients, without loss of consciousness and a Glasgow Coma Score 13-15, do not require CT scanning unless there are other clinical indications. The reports recorded above applied mainly to adult patients. Rivara et al(1987) had warned of translating data applicable to one group to another. Studies exclusively on children are far less frequent, and comprehensive.

Ros and Ros(1989) undertook a study to determine the incidence of complications in patients already hospitalised, with normal cranial scans following minor head injury, and a Glasgow Coma Score of 13-15. 73 patients were included in the analysis, 63 of whom had a Glasgow Coma Score of 15 on arrival. Patients were predominantly male. Motor vehicle accidents accounted for more than half of the injuries, and 40 had a history of loss of consciousness. None developed complications, and all were discharged well 48 hours later without follow up. The authors concluded that patients with a Glasgow Coma Score of 15, normal neurological examination, and a normal CT in the emergency room, can be safely discharged home. No criteria for admission were given in this group of patients. None appeared to have had xrays. It is possible that the history of loss of consciousness was the main criteria for admission for observation?

Rosenthal and Bergman(1989) retrospectively evaluated the records of 459 children who had normal neurological examination after what was termed moderate injury. These authors used Masters(1987) categories which selected the severe group only, for CT scanning. Minor head injury was eliminated from skull xray, leaving a moderate group to be investigated at the discretion of the emergency physician. Children were to be consigned to this group, because of problems with head injury assessment. Children were categorised by a brief loss of consciousness. 40% had skull fractures. Intracranial complications developed in six. Five developed extradural haematomas and one bifrontal contusions. All these patients had skull fractures. Three required neurosurgery. CT scanning was used in only 10 patients in this series. The authors concluded that in the child population studied, and with a range of clinical features, only skull fracture was significant, along with the fact of admission to hospital. The data suggests however that apart from skull fracture, loss of consciousness resulted in admission. The authors concluded that the detection of a skull fracture is a valuable marker for the risk of developing an intracranial haematoma. Fischer, Carlson and Perry(1981) had reported fractures in all their patients with intracranial haematomas, who were alert in the emergency department, and Dacey et al(1986) had reported fractures in three quarters of such patients. Rosenthal and Bergman(1989) commented on the literature which had reported that the presence of a skull fracture increased the likelihood of an intracranial haematoma by 200-400 times in comparison with patients without a skull fracture. Patients who are not alert and orientated however have a greatly increased risk. The risks for adults had been established by Mendelow et al(1983) and more recently have been calculated by Teasdale et al(1990) for children. Rosenthal and Bergman(1989) discussed the features which would allow a child to be discharged from the emergency room, following apparently moderate head injury.

Davis et al(1995) examined the value of CT scanning in the triage of paediatric patients with mild head injury. He examined the records of 400 paediatric patients, defined as under 18 years of age. These were subject to CT scans in the emergency department of the Harbour View Medical Centre. The study was retrospective, and based on emergency records, and follow up at one month. The patients were selected by two mechanisms. The setting was a tertiary referral centre, and the children may therefore have been more seriously injured than those attending in the primary setting. The criteria for selection for CT scanning were not defined, but not all children with head injury, according to the authors, justified CT scans. The patients who had scans were however all in the minor head injury category, as defined by a Glasgow Coma Score of 13-15. It was stated a history of loss of consciousness was not taken into account in selection for CT scanning. The injury characteristics included a loss of consciousness greater than 5 minutes, amnesia and seizures in more than 100 patients, which others would consider required inclusion in the moderate head injury group. Admission was recorded in 263 patients.

From 110 discharged from the emergency department following normal CT scans 4 required admission within a month. Complication rate was 4% though only one required neurosurgery. This was a child on anticoagulant therapy, who perhaps should not have been discharged initially? None of the admitted group developed intracranial bleeding. The author concluded that a negative CT scan in the emergency room, combined with the absence of any clinical neurological abnormality, allows triage for the safe discharge of the child home. No information was offered to compare this group with children discharged from the emergency room, without CT scans.

Hoffman(1996) reviewed the article by Davis referring to the attempts to identify children who can be managed safely without CT scanning, or admission for observation. The magnitude of the problem was acknowledged, because so many children present to Emergency Departments each day. It was essential in Hoffman's view that guidelines needed validation, before they could be promulgated for general use. Hoffman stated that when evaluating children with head trauma, the emergency physician was charged with identifying both acute lesions requiring emergency treatment, and patients at risk of delayed complications. He said CT scan at the time of presentation is the best test to identify acute surgical lesions. Taken too early, it may be negative, in some patients who subsequently deteriorate.

He felt that professional observation after admission was the best way to recognise deterioration, before it became significant, but did not in itself identify acute haemorrhage. Safety in discharging children remained in question. He did not feel that firm conclusions about when CT scanning is unnecessary were possible, and the issues extend beyond purely clinical considerations, particularly in childhood.

Contributions to the management debate have been made by Stein, O'Malley and Ross(1991), Stein and Ross(1992) and colleagues.

Deitrich et al(1993) in a study on 322 patients and 324 CT scans, undertaken prospectively in an extended (20 years) paediatric group, where males dominated 62%, found 12% had intracranial abnormalities, almost half with a skull fracture. There was a statistically significant association, when a history of loss of consciousness, amnesia, Glasgow Coma Score less than 15 and a neurological deficit $P<0.05$. 5% of patients with a GCS 15 had an abnormality. The author concluded there was poor correlation between clinical symptoms and CT scan findings. By contrast, despite the evidence available, some of which have been reviewed, Duus et al(1993) reported that radiological imaging did not have a place in mild head injury management. He was satisfied with the value of clinical observation, but had a very high admission rate - an expensive alternative.

As recently as 1997 Quayle et al observed that despite the frequent occurrence of head injury there is no agreement about clinical criteria which identify the need for diagnostic imaging, be it skull xray or CT scanning in the A&E Department. A prospective study on 322 children in an urban paediatric emergency department was set up. Information was collected for each patient, including age, mechanism of injury, symptoms, clinical signs, neurological deficits – data comparable to this Study(MTB).

Diagnostic imaging was undertaken using skull radiography and CT scanning.

Skull xrays revealed 50 skull fractures, 16%. Intracranial injury was detected in 27, 8%. 59% of the children with intracranial injury had normal mental status and no neurological abnormalities, including one child with an epidural haematoma revealed on CT scanning. It is not clear whether this child had a skull fracture.

Clinical features associated with either skull fractures or intracranial injury or both were analysed using statistical methods. The chi squared Test, x^2 was used to test univarate associations between clinical features and intracranial injury. When the expected counts were less than 5, P values were calculated using Fischers Exact Test. The t test was used for calculation of the only continuous variable – age.

P values were considered significant when less than .05. The values between 0.05 and 0.1 were considered to represent a trend.

Multivariate analysis was used to determine the presence and strength of association between multiple features and intracranial injury. A stepwise logistic regression was performed. Variables that retained an association within intracranial injuries with $P< .05$ were considered independent predictors of intracranial injury. These methods are given in detail as similar analysis was undertaken on a much larger number of children attending the A&E Departments in this Study(MTB).

The results reported by Quayle et al(1997) show male dominance and causes of injury were similar, but children were included up to 18 years of age.

74% per discharged home, the higher admission rate suggesting more significant head trauma than in my unselected A&E population (MTB).

Quayle's univarate analysis revealed altered mental status, focal neurological deficit, signs of basal skull fracture, loss of consciousness of more than five minutes and skull fracture as significant predictors of intracranial injury.

Quayle concluded that intracranial injury may occur with few or subtle symptoms or signs, especially in the infant. The relative risk for intracranial injury is increased four fold by the presence of a skull fracture. However, the reverse is also true as intracranial injury can occur in the absence of a skull fracture.

The significance of non neurosurgical intracranial injury in neurologically normal children required, according to these authors, further study. They did not, however, address the relationship of skull fracture to intracranial haematoma – only one extradural haematoma was identified in their cohort.

The authors, from their data, and a review of the literature, developed guidelines for implementation in their own practice. They outlined the criteria for CT scanning and recommended that where CT was not readily available, skull radiographs provided screening information, noting particularly the relative risk of intracranial injury, which was greatly increased in the presence of a fracture. They identified the infants as requiring a special approach, both because of the evaluation of non accidental trauma and also because clinical evidence of intracranial injury in infants was often associated with few or subtle signs and symptoms.

Lloyd et al(1997) reported on a study of Diagnostic Imaging including, skull radiography and CT scanning. Radiography as a predictor of intracranial injury is controversial. Lloyd undertook a prospective study on children admitted via the Accident Department to a children's hospital. 9,269 children attended and 6,011 were subject to skull radiography, a skull xray usage of 67% confounding the claim of routine skull radiography by Casualty Medical Officers. 883 children were admitted to hospital. These included children with skull fractures and those with abnormal neurological signs or symptoms. Skull xrays in the Accident Department had identified 162 fractures, (2.7% of all the radiographs and 18% of the study group). Though 23% of fractures were missed by the casualty doctors is not a justification for condemning the investigation, rather for teaching inexperienced doctors or ensuring those who order xrays are capable of interpreting them correctly. CT scanning was undertaken on 156 children of whom 107 had skull fractures. 23 had intracranial abnormalities. Lloyd found that neurological abnormalities had a greater predictive value than skull fracture, 91% (21 of 23), whereas skull fracture resulted in values of 65% (15 0f 23).

Lloyd et al(1997) noted that severe injury can occur in the absence of skull fracture which is of course true. However, it is unlikely to occur without significant symptoms and physical signs which would result in admission and further investigation. For this group CT scanning is indicated from the outset. Criteria are already incorporated into the guidelines and the examination will confirm and define intracranial abnormality. This is the policy generally used in the United States of America. Teasdale et al(1990) supports this approach but in addition recommends skull xrays for fully conscious children with defined criteria.

The value of skull fracture in identifying intracranial complications has been reported by Chan et al(1990), Rosenthal and Bergman(1989), Reid et al(1995), Bonadio et al(1989) and Gordono et al(1992). These last authors were converted from their view that skull fracture was not a significant predictor and retracted views that they had expressed earlier.

Lloyd et al(1997) claimed that the risk of intracranial haematoma was rare and claimed absence of a skull fracture may reassure health care staff. Children considered to be at risk they thought should be admitted and observed. The alternative would be to scan these children in the Accident & Emergency Department. If negative admission should be avoided. The rarity of the condition is not a reason for making it insignificant for the individual patient. Similarly inexperienced doctors misinterpretation of skull xrays does not negate the potential value of the examination, rather that doctors be appropriately trained or experienced. Lloyd agreed the value of skull xray for depressed fractures. The problem is that frequently this is not suspected and xray may not be requested. The view expressed that this condition is not immediately life threatening cannot be accepted if the fracture is compound with the risks of intracranial infection.

The authors recommended skull xrays in infants because of difficult assessment, though they claimed the risks of intracranial injury was less. There is no mention of complications of skull fracture in the form of growing fractures in this age group, though the question of child abuse is a further justification of xray.

One would not disagree that children with symptoms or signs should be admitted regardless of the detection of a skull fracture either for CT scanning or for a period of 12 hours observation.

No consideration is given for CT in the Accident & Emergency Department, whether a skull fracture is detected or not, to avoid the more expensive disruptive admission. Though Teasdale's(1990) work is noted, his view that CT, following the detection of a fracture, will identify haematoma and ensure expeditious neurosurgery in those who initially may have no indication for CT scanning, is not accepted.

The argument against CT in the A&E Department in children manifesting a variety of symptoms and signs is the need to tranquillise or anaesthetise the uncooperative patient. This is a serious concern for A&E and anaesthetic staff. Admission for six to 12 hours in this group may be a reasonable option, though CT scanning may subsequently be indicated.

The limitations of their paper are identified by Lloyd and his colleagues, but unfortunately the findings cannot be extrapolated to the paediatric head injured population in the Accident & Emergency Department, as their cases had already been selected for admission.

7. Discharge Disposal from the Accident & Emergency Department

7 (a) Review - Mild Head Trauma

The patient whose discharge home or requirement for admission exercises the skill and judgement of the emergency physician, is one who has sustained a blow to the head. There is possibly a history of brief loss of consciousness, of no more than five minutes, and is apparently recovering, without evidence of any neurological deficit, or significant symptoms when seen in the Emergency Department. In the past such patients have been classified as concussed, and systems are available to categorise them(Becker et al 1982., Ranschoff and Fleisher 1975., Nelson, Jane and Gierk 1984). The Glasgow Coma Scale(Teasdale and Jennet 1974) has been used to classify head injured patients, and seems to be fairly widely accepted for this purpose. Mild-Glasgow Coma Score 13-15, Moderate-Glasgow Coma Score 9-12 and Severe Glasgow Coma Score less than eight. Patients with mild head injury are frequently hospitalised for 24-48 hours, and numerically represent a substantial drain on clinical resources. 100/100,000 per year in the U.S.A.(Kalsbeck et al 1980). 100,000 per annum in the U.K(Jennett 1981).

The decision to discharge a patient following head injury, normally follows a clinical assessment and investigation. In the U.K. skull xray, was until recently, the commonest investigation, to exclude a skull fracture. In a minority exploration of a scalp wound may have been used as an adjunct to the exclusion of skull fracture(Fullarton et al 1987).

A history of loss of consciousness has also been used to triage patients, including children, for admission or discharge home. When the emergency doctor is satisfied that no serious injury has occurred, and following the exclusion of fracture, has judged there is no, or little risk of an intracranial complication developing, the patient is discharged in the care of a responsible adult.. Head injury warnings are issued in writing and explained verbally. Any symptoms of headache, vomiting, drowsiness, visual impairment, seizure or any unexplained problems are to result in the child being brought back urgently to the hospital. There is no standardisation of head injury warning sheets in the UK. This is currently the subject of an A & E Departmental Survey, as yet unpublished. Cline and Whitley (1988) and Saunders, Cotar and Barton(1986) have questioned the reliability of head injury warning sheets, but it seems likely that the deficiencies identified are more likely to affect adult patients. There is no doubt that the observation of the head injured child at home may be a source of concern both for the carer, and for the physician. Even with a telephone and readily available transport, a deterioration, though a rare event, may result in delay and less favourable outcome. The vast majority of discharged children come to no harm, as was demonstrated in this Study.

The increasing involvement of Accident & Emergency Consultants in initial head injury care, has given them a role in the supervision and continuing observation of the patient, considered to have sustained a minor head injury, but who may be at risk of developing a complication. The complication, which causes greatest anxiety, is that of intracranial haematoma, though depressed skull fracture, with the risk of infection, must be excluded. Patients with a base of skull fracture rarely fall into the category of minor head injury, and should be admitted routinely and scanned.

The extended head injury care under the supervision of Accident & Emergency Consultants has resulted in the development of Short Stay Wards. Dedicated facilities for children are rare outwith Paediatric Hospitals Such provision was made by Beattie and Moir(1993). They found the head injured children formed the largest group of those admitted over a year. Only one required a CT scan. The majority were discharged, within 24 hours. Those who remained longer had intercurrent infections, or other injuries. When a short stay facility is not available, the child is admitted under a consultant in a primary surgical or paediatric ward.

The purpose of such admission for observation in the past was to monitor progress, and to detect as early as possible any deterioration, indicating the expansion of an intracranial mass lesion with its lethal potential. Having detected that deterioration, the patient would be urgently transferred to Neurosurgery. The realisation that detecting deterioration, was frequently associated with avoidable delay, and poor outcome, prompted a search for predictors of deterioration. These would allow selection for admission of those at increased risk. Those not demonstrating a risk feature, would be allowed home, ensuring better standards of supervision for those admitted.

The detection of a skull fracture is associated with a risk of intracranial haematoma(Mendelow et al 1984). The demonstration of a skull fracture is an indication for admission. This was incorporated into the Guidelines for Head Injury management in adults devised by a Group of Neurosurgeons(Briggs et al 1984, Teasdale et al 1990) have shown a similar association for children.

A history of loss of consciousness had long been considered a risk factor requiring observation. It was expensive, large numbers at virtually no risk, were observed along with those at greater risk. The resources were spread thinly, with less than adequate care for those whose condition might deteriorate from a mass lesion, or raised intracranial pressure. In order to avoid the admission of large numbers of patients, alternative admission policies were tested by Jones and Jeffreys(1981). If only patients with a history of loss of consciousness received skull xrays then significant numbers of patients at risk would be missed. This report was on mainly adults patients.

The Harrogate Neurosurgical Guidelines(1984) are based on the assumption that a minority of patients with skull fracture, and a history of loss of consciousness or impairment at the time of examination, may proceed to manifest an intracranial complication. Mendelow et al(1982) reported intracranial haematoma in 1.3% of 865 patients initially alert and orientated. He subsequently analysed several thousand patients and found a haematoma rate of 1.5% in observation wards. Then he calculated the statistical risks of haematoma in those alert and orientated, with no skull fracture 1:6,000 Patients with a skull fracture and impaired conscious level had a risk of 1:4(Mendelow et al 1984).

In the UK, the Guidelines of a Group of Neurosurgeons were endorsed by the Department of Health. They have found wide acceptance, although implementation is less than complete in some reports. The document carries authority, and is helpful in meeting medicolegal challenges. There is always the problem of matching the guideline to the patient. This guidance was intended for application to adults. Children were specifically excluded, because of differences between the younger patients, and adults. However Teasdale et al(1990) subsequently assessed the risk of intracranial haematoma in children. The same criteria are applicable, although the risk is lower statistically. Children with skull fractures are recommended for CT scanning.

Using loss of consciousness as a criterion, Gorman(1985) undertook a retrospective review, and a prospective study to evaluate a protocol which allowed patients to be discharged home, even if they had a history of loss of consciousness of less than five minutes, and amnesia, providing they had no skull fracture. His study involved 12,453 adults and children, the children forming approximately 40% of patients. They had attended in a District General Hospital. At the time Gorman had noted that admission rates for children had already fallen. The rate in 1973 for children with intracranial injury was 40%, and 26% for children with fractures of the skull. By 1978 there had been a further fall in both categories. In his prospective study Gorman confirmed, that as loss of consciousness is less common in the younger patient, the new policy would affect them less. This proved to be true.

Fischer, Carlson and Perry(1981) had reported on a series of 420 patients, 333 of whom had a class I level of consciousness. 2.4% or eight patients required neurosurgical procedures, five for depressed fractures of the skull, and three for subdural haematomas. This author emphasised the importance of neurological findings, as opposed to a coma scale system, emphasising that there may be subtle evidence of neurological impairment, even in those whose Glasgow Coma Score is 15. Reports of CT abnormalities in those with a Glasgow Coma Score of 15 supports this view. Dacey et al(1986) in an analysis of 610 patients had found that 3% required a neurosurgical procedure, despite an initial Glasgow Coma Score of 15. His patients were predominantly adult.

Much of the literature, including that quoted above, relates to minor head injury in adults. Children are inevitably different, not only from adults, but from children of different ages. Admission policies have to err on the side of safety, in children following "minor" head trauma. Detailed analyses by comparison, are infrequent in the literature for children in Accident & Emergency Departments compared with adults. A history of loss of consciousness may be difficult to confirm in the child, unless the episode is witnessed by a reliable peer or adult. Children in any case vary at different ages in their susceptibility to lose consciousness, compared with adults with a similar mechanism of injury. Children over 3 years of age can be assessed using the Glasgow Coma Scale - infants require a paediatric scoring system.

Admission policies for all patients vary considerably in the United Kingdom, Europe and the United States of America. Some Neurosurgeons recommend admission for patients, where there is any history of loss of consciousness. Others allow discharge home when there is full recovery at the time of examination, and no cerebral abnormality or significant symptom. Such patients are discharged home with warnings and supervision.

In the United Kingdom the situation with children has always been more liberal. Any history of loss of consciousness, or the presence of a skull fracture usually results in admission, despite the views of many in radiology that skull fracture does not influence management. Children are less readily rendered unconscious. It seems possible therefore, that confirmed loss of consciousness in a child reflects more severe cerebral impairment. Children, are more likely than adults to develop cerebral swelling, and raised intracranial pressure, after even minor injury; and some may die(Bruce, Alavi and Bilaniuk 1981., Snoek, Minderhoud and Wilmink 1984., Humphreys, Hendrick and Hoffman 1990).

Children who continue to vomit after head trauma are a source of anxiety. Childhood concussion syndrome(Oka et al 1977) generates concern, and a requirement for exclusion of more serious pathology and observation.

Seizures(Jennett 1975., Annegers et al 1980) following trauma, also warrant admission for observation, treatment and appropriate investigations.

Children with recent head trauma may be subject to intercurrent illness, with symptoms inseparable from head trauma, and assessment may prove difficult. The ill child, who has also sustained a head injury, generates anxiety and emotion in parents and physicians, putting pressure on the doctor for exclusion of all risks of complication, and immediate access to diagnostic and treatment resources.

The diagnostic tool, which promised to resolve these dilemmas, is CT brain scanning. The detection of intracranial pathology in patients in the minor head injury group, with a Glasgow Coma Score 13-15 was reported, by several authors(Moran, McCarthy and Udding 1994., Davis, Hughes and Gruber 1995., Stein and Ross 1990., Stein, O'Malley and Ross 1991) and has confirmed that mild trauma is far from trivial. In this category deaths still occur, and delay is associated with increased morbidity. The majority of the reports however do not necessarily separate children from adults.

This research has confirmed the large numbers of children who attend hospital having sustained minor head trauma come to no harm. It would be impracticable to subject all to CT Scanning, to detect that small number with a surgical lesion. A system of triage for CT scanning is required. Skull fracture is one feature which has been shown, in adults(Mendelow et al 1984), but less frequently in children(Teasdale et al1990), to serve as a predictor for an intracranial haematoma.

A history of loss of consciousness, or any impairment of conscious level, requires further investigation and/or observation. Minor head injury alone, and no history of loss of consciousness, in children who are otherwise asymptomatic, may allow discharge from the Emergency Department, after negative skull xrays.

Radiologists might suggest that a period of hospital observation could be used as an alternative to both x-ray and CT scanning. Admission is expensive, disruptive, and distressing for a child, and for the family. Scanning in the majority of situations could prove a more cost effective system of management.

The patient in the moderate injury category, Glasgow Coma Score 9-12, will inevitably be admitted, observed and investigated, as will those who are clinically diagnosed as having suffered a base of skull fracture. Such patients are admitted for formal continuing assessment, and specific treatment rather than for observation only.

7.(b) Moderate and Severe Head Injury - Neurological Trauma and Complications

The extent of the head injury problem in childhood was identified by Raphaely et al(1980) in a paper presented at a symposium on paediatric intensive care. Five million children in the United States sustained head injury each year. 200,000 are hospitalised, 4,000 die. Many die within two hours, suggesting primary brain stem trauma. 15,000 required prolonged hospitalisation and half are severely injured and permanently disabled.

Raphaely et al(1980) discussed in detail the initial assessment, investigation, management and outcome of severely injured children. Similar publications have come from Bruce and Schut(1979), Gennarelli(1984), Jhajar and Hariri(1992) Rosman, Oppenheimer and O'Connor(1983) and others. Many of the lessons to be learned about the care of paediatric head injury have been summarised by these international experts in the field over some decades. Yet it would appear that this wealth of knowledge is not reaching many who are responsible for the initial care of children with head injury(Sharples et al 1994). Only prevention can reduce the toll of primary injury. The injured are dependent on the quality of care offered, to reduce their disability, and to avoid complications. This has implications for pre-hospital care, and management in the Emergency Room, and the interrelationship between Emergency Services and Neurosurgical Units.

Triage and Assessment of Traumatised Paediatric Patients

Systems of care for the traumatised patient, of whatever age, have in the past two decades, received recognition internationally, though effective implementation still presents many problems. A systematic approach from injury to definitive care is essential and is not controversial. The physical environment in which delivery is effected still produces discussion, controversy and practical problems for implementation in the United Kingdom. The National Trauma Centre is currently being evaluated. A specific contribution to the care of children has not yet been published. In the interim it is essential that the Units to which injured children are taken are competent to supply efficient and timely resuscitation, and provide access to specialist services with appropriate intensive care support. Wherever possible, paediatric surgeons should be involved at an early stage, and when available, should probably lead the resuscitation team, identifying priorities of care and effecting their implementation.

The advent of paramedics and the acceptance of the concept of triage should ensure optimum prehospital management, and arrival at a centre with a team already prepared for the reception of the victim. There should be clear identification of responsibilities. Initially this may be the A&E consultant or the most senior A & E doctor immediately available on site..

The injury sustained may be suspected and diagnosed from the mechanism of injury. A child with multiple injury from a motor vehicle accident, or fall from a height may have both serious limb and torso trauma, with a severe primary brain injury. The less severely injured brain may be put at risk of secondary damage by inefficient management of other injuries, with secondary insults to the brain.

The majority of children presenting in the Accident & Emergency Department with head trauma will have sustained only minor injury. A minority will have sustained serious or potentially serious, brain trauma An even smaller number have multiple injuries which may threaten the integrity of the brain. . Management decisions in the Accident & Emergency Department are dependent upon an understanding of the pathophysiological changes, which occur at, or following the impact injury to the brain. Concepts of pathology have changed, as knowledge has accumulated from research world-wide. Information is of more than academic interest, because "rational treatment is based on assumptions about the pathophysiological processes, which treatment aims to modify".

The management of the minority of children with moderate or severe injury, their resuscitation and priorities of care and transfer to specialist facilities are discussed in Appendix 8(b).

8 Intracranial Haematoma

8(a) Extradural Haematoma

Perhaps the most eloquent review of extradural haematoma was undertaken by Hooper(1959), incorporating his experience of 83 cases of extradural haematoma over an 11 year period in the Royal Melbourne and Children's Hospitals. There have also been many reports published for both adults and children(McKissock et al 1960, Jamieson and Yelland 1968, Zucharello et al 1983, Rivas et al 1988, McLaurin and Ford 1964, Choux, Grisoli and Paragut 1975, Dhellemmes et al 1986, Reddy, Sathynarayank and Rao 1977, Mazza et al 1982, Phonprasert et al 1980, Mann, Chan and Yue 1986).

Hooper(1959) in a wide ranging examination of the literature, from 1867 to the date of publication, was concerned at the high level of mortality, on average 50%, which was reported in some series. He noted however, that at the time, rates of less than 30% had been achieved. Commenting on the relative rarity of the condition, he emphasised the importance of teaching doctors in training so as to ensure the diagnosis was made, and urgent action taken when the doctor was confronted with this emergency. Rare in infancy, Hooper recorded a peak incidence at the age of eight years, the condition was most frequently seen between the 6th and 10th years. This was also reported by Garniak(1986) in male children in the first decade of life. In adults the peak occurred in the 3rd decade. A rapid decline occurred after the 5th, but no age was immune in his series. Hooper considered the causes and mechanisms of primary impact. He reported that the condition was rare as a complication of a compound fracture of the vault, but three of his cases occurred with compound basal fractures adding the risk of infection to that of haemorrhage.

Comparing causes of injury with those reported by Jacobson(1886), it was evident that social evolution influenced patterns, road traffic accidents, causing a four fold increase. Nevertheless, the association of extradural haematoma with so called mild injury still obtained. More than half the road traffic accidents were termed mild, as the impact was deemed to be low velocity.

In those who had fallen, 44, one third, fell from a standing position, a quarter more than 12 feet. In those sustaining blows, only four were rendered unconscious, and only one sustained what was termed severe injury. Hooper concluded that in his experience this serious and life threatening complication of intracranial bleeding, follows relatively minor injury. He proceeded to pursue explanations for this phenomenon in detail.

The association between the impact and the site of major arterial vessels and venous sinuses had been demonstrated by Gurdjian and Lissner(1947), Copolla(1973) and

Vogel(1977). Correlation between the site of impact, and the fracture, and bleeding produced they claimed was predictable. The vulnerability of the meningeal vessels, in the temperoparietal region, was emphasised. Signs of external injury to the head were said to be commonly present. The relationship of the abrasion or haematoma of the scalp (the head to be shaved if necessary) to the underlying haematoma was a reliable guide to the site of bleeding, and correlated more consistently, than the site of the fracture. The mechanism whereby the impact facilitates the dural stripping and subsequent bleeding was considered, and the physical principles defined. The alternative of primary haemorrhage producing secondary dural stripping and elevation was also suggested. This mechanism is probably related to anatomy at different ages, and may account for differences in children and adults.

The physical features which might explain the particular high incidence in the 6-10 year olds was not specifically discussed by Hooper(1959), though it has been noted that the dura is less firmly adherent in this age group, than in the very young child. The effects of extradural bleeding were essentially those of an expanding intracranial mass, and are reflected in the clinical features, both general and local. In Hooper's series the relatively minor nature of the injury was shown, by the absence of loss of consciousness in 21 of 83 cases. Transient loss of consciousness only, occurred in a further 24. 37 had the classical lucid interval. Deterioration or delay to operation in this series, as in subsequent reports, was associated with a high mortality: 16 out of 48 deaths.

In Hooper's paper, not all the lesions occurred at the temperoparietal site. Frontal injury was seen with anterior fossa fracture, temperoparietal injury with middle fossa and occipital with posterior fossa haematomas. In almost all of Hooper's patients the external injury overlay the haematoma, whilst the fracture could be peripheral to the lesion. Bleeding at sites other than the temperoparietal may cause difficulty in diagnosis for the casualty officer, particularly if the condition is complicated by diffuse axonal primary injury, or more than one haematoma, or intracerebral bleeding.

Hooper emphasised the site of injury on the scalp, and the side of the pupillary change, and the location of the fracture and scalp haematoma as a better guide to the location of the intracranial mass.

The minor nature of the initial injury has been reported by Klauber et al(1989).

Clinical Features

The clinical features of patients with acute intracranial haematomas have been the subject of many studies. A comprehensive review is provided by Bullock and Teasdale(1990). Choux(1975) has described extradural haematoma in children, as have others(Dhellemmes et al 1986, Reddy, Sathynarayank and Rao 1977, Mazza et al 1982, Phonprasert et al 1980, Mann, Chan and Yue 1986).

Clearly there will be variation depending upon whether the haematoma occurs in isoloation, or complicates more severe diffuse or complex intracranial injury. Timescales too may be different. The classical abnormality to be monitored is loss of consciousness. As extradural bleeding may occur following a minor injury, there may be no loss of consciousness, or only a brief impairment. In these patients headache, vomiting and neurological signs are of importance, not only in their presence, but in increasing severity. The symptoms precede the development of raised intracranial pressure, and the progressive deterioration in level of consciousness. If disregarded the patient will progress to pupillary changes and alterations in vital signs, due to compression from an expanding mass lesion, with tentorial herniation.

Change in Conscious Level

Different patterns of altered consciousness occur both in the adult and in the child population. Five patterns have been described by Jamieson and Yelland(1968). 50% of patients may never lose consciousness at the time of injury, and this was common with extradural haematoma. 80% of patients were conscious for some period before the diagnosis was made. The classical loss of consciousness followed by a lucid interval, followed by deterioration occurred in only 13% of cases. Though Hooper(1959) described it in 43%, it is not unique to extradural haematoma, but can occur in some cases of intradural bleeding. In the patient unconscious from the outset CT scanning must be requested urgently, to exclude an additional mass lesion, complicating diffuse primary injury. In childhood Choux, Grisoli and Paragut(1975) noted 57% of children, and 85% of infants, had no loss of consciousness at the time of the injury.

The other classical features of intracranial haematoma are headache, usually increasing in severity, associated with vomiting. It may need to be differentiated from subarrachnoid bleeding. Headache particularly associated with lethargy, irritability and restlessness is important in the child, and may be the first indication of an expanding haematoma.

Neurological Deficits

If the condition is allowed to deteriorate, lateralising neurological deficits will be detectable, usually in the form of hemiparesis or hemiplegia. This is normally on the contralateral side, though occasionally it is seen on the ipsilateral side to the haematoma. This is known as Kernohan's phenomenon.

Pupillary Changes

Pupillary changes associated with intracranial haematoma are a sign of impending disaster. Pupils may be quite labile in childhood, and may be misleading. However a deteriorating level of consciousness with pupillary changes, is significant particularly when normal size and reaction has been registered immediately following the accident. A recent change in the size of the pupil occurs on the side of the haematoma in more than 90% of patients(Teasdale and Galbraith 1989, Epstein, Ward and Becker 1989).

Seizures

Seizures associated with intracranial haematoma are more commonly seen in children than in adults, and are an indication for urgent CT scanning.

Investigations

As the majority of patients with extradural haematoma will have sustained what is considered to be a minor injury, CT scanning is unlikely to be undertaken routinely, in the United Kingdom, at the present time. The value of a skull fracture is however relevant to decisions to discharge home, admit for observation or triage for CT scanning. A child with the classical history of minor injury, and skull fracture must have a CT scan.

The risks for intracranial haematoma were reported by Mendelow(1983), and related to skull fracture and level of consciousness. These were applied to adults only. More recently Teasdale et al(1990) have incorporated further features, and reported on the risks of haeamtoma in both adults and children.

The identification of a skull fracture puts the patient at a significantly increased risk of intracranial haematoma. Urgent CT scanning to detect a possible intracranial haematoma, prior to any deterioration, is indicated. If negative, the patient should be observed in hospital till fully conscious, or recovered. If progress is not satisfactory, repeat scans should be undertaken. The detection of a haematoma should result in urgent neurosurgical consultation and transfer.

Extradural haematoma and age of the child

Extradural haematoma is not common in childhood(Ingraham, Campbell and Cohen 1949) and is less common than in adults. The clinical presentation varies in some respects from adults. The classic bleeding from the middle meningeal artery may not be the source in children. Venous bleeding occurs in a minority, 25%. The progress clinically is more slow. Children may not lose consciousness, at the time of injury, which might seem quite mild. There may be, therefore, no lucid interval. Some children may have evidence of extradural haematoma and remain conscious. The classical picture may be seen after trauma at the temporal site, though some authors suggest that the parietal site is more commonly affected in childhood. Extradural haematomas can occur both in the frontal and occipital regions. Diagnostic difficulty may result. The presence of a fracture may be a clue to the potential for a mass lesion to develop. If the posterior fossa is the source of bleeding it is usually venous in origin. The incidence of radiological fracture may be lower, and the deterioration more slow - the features different.

In older children where the condition is infrequent, the presentation is different to that in adults. There may be no history of loss of consciousness, and the head trauma may be regarded as minor. There is frequently no lucid interval. More than half the children and 85% of infants have no loss of consciousness according to Choux et al(1975). An exceptional presentation is a conscious child, with raised intracranial pressure and bradycardia.

There is a group of children who seem to be at particular risk: males between the age of seven and 10 years who fall from bicycles. These were noted by Hooper(1959) and by Garniak et al(1986), and may be related to dural attachment at this age. It has been stated that children have a lower frequency of fracture. In fact fracture is present in 75% of extradural haematomas in childhood. The confusion may occur in the absence of a detectable radiological fracture. This is possibly due to the flexibility of the skull, which allows a focal impact to strip the dura, without clear evidence of fracture. Some negative x-rays are due to clinical misinterpretation, and represent a high risk, and a source of false security. Fractures not seen radiologically, have been described at operation, and at post mortem.

Alternate sites of injury and extradural haematoma

In childhood extradural haematoma is associated most frequently with injury at parietal amd temporal sites. It can however occur, infrequently, in the posterior fossa.

Posterior fossa haematomas

Haematoma in the posterior fossa is rare. The condition follows occipital trauma, often associated with an occipital fracture. This may provide the clue to the condition in an atypical presentation. Half the patients remain conscious, and are lucid when seen. Neubaeuer(1978) described nystagmus in 39% of patients. Some have long tract signs, but of particular importance are disturbances of respiratory function, which can lead to respiratory arrest. This occurred in 40% of those initially conscious, and 70% of those in coma, in his report.

The progression of the condition may be slow, as described(Sadik, Epstein and Ransohoff 1978) in a three year old child. Following a fall, resulting in an occipital blow, there was no loss of consciousness, but vomiting and lethargy was observed. After a stable condition over 12 hours, there was a sudden deterioration. An extradural haematoma of the posterior fossa was evacuated. A fracture in the occipital region had been missed on admission.

The condition was first reported in 1938 by McKenzie. Since there have been increasing publications in the literature from McKissok et al(1960), Hooper(1959), Kosary et al(1966), Wright(1966), and others. All document occipital trauma, frequently with a fracture. In the early series the mortality was high. Fisher, Kim and Sachs(1958) analysed the features of 98 cases of occipital fracture, and reported eight extradural, four subdural and three intracerebral haematomas. Clearly the skull fracture alerts the clinician to the potential for serious, and life threatening complications. It should secure urgent CT scanning and admission for observation, and justifies skull xray in minor injury.

Anterior fossa extradural haematoma

The condition is associated with frontal trauma, not infrequently the result of a road traffic accident. Skull fracture is common, and justifies the skull xray.

Bilateral extradural haematoma.

These are rare as reports over 30 years have shown. They are complications of severe injury. Bilateral fractures and unconsciousness, place the patient in the severe injury category, requiring urgent CT scanning.

Delayed intracranial bleeding and haematoma.

This may occur into areas of cereberal contusion, and are rarely presented to the emergency physician.

Special considerations - Haematoma risk.

The vulnerability of children to complications following head trauma, associated with disorders of haematological function are best known in association with genetic abnormalities, such as haemophilia. This information is usually conveyed to the physician. Eljamel and Rugman(1989) reported a posterior fossa haematoma in a child with thrombocythaemia. Stein, Young and Raymond(1992) warned of the risk of coagulopathies and intracranial haemorrhage. A significant correlation between longer prothrombin time and partial thromboplastin time on admission, and delayed bleeding was confirmed. Platelet deficiency did not reach statistical significance in relation to complications.

The cases illustrated the importance of obtaining a relevant history of impairment of coagulation mechanisms, resulting either from genetic deficits, iatrogenic interventions, previously undiagnosed haematological disorders, anticoagulant therapy, and severe liver disease. The importance of the bleeding time has recently been emphasised by O'Hare and Eden(1994).

Severe brain injury may itself initiate a cascade of responses, culminating in Disseminated Intravascular Coagulopathy.

Coagulation screening should be part of the initial investigation of all, but the most trivial head injuries in the Accident and Emergency Department and an appropriate history should be sought of any other pathology, genetic predisposition or current infection in childhood.

8 (b) Subdural haematomas

Subdural haematoma is most common at the extremes of life. It was described by Hendrick, Harwood-Nash and Hudson(1964) in a series of 4,465 children, as being highest in frequency under the age of two years, and particularly under two months where it reached 20%. It was described in post mortem cases following assault with an incidence of 42% between birth and five years. Subdural haematomas occur in childhood, as a result of the application of acceleration/deceleration forces sufficient to rupture the bridging veins. The mechanisms have been demonstrated experimentally by Gennarelli and Thibault(1982). The application of high energy deceleration forces in the anterior/posterior plane produced pure venous subdural haematomas in experimental animals. When high energy deceleration forces were applied, particularly involving a rotational component, subdurals became less frequent, and extensive contusions were produced. These were more comparable to motor vehicle accidents. There is relevance to patterns of abuse.

Rosman(1982) contrasted the frequency of features of epidural and subdural haematomas in childhood. Epidural haematomas are less frequent than subdurals. 75% of extradural bleeds are associated with skull fracture, compared with 30% for acute subdural bleeding. In the epidural lesion the bleeding is usually arterial, though in 25% in childhood there may be a venous origin. Epidurals occur most commonly in children over the age of two years and the lesion is usually unilateral. By contrast subdural haematomas occur most commonly in infants and may be bilateral. Seizures occur in less than 25% of epidural haematomas and in more than 75% of subdural haematomas. The latter may also be complicated by retinal haemorrhages in 75% of cases. Both epidural and subdural haeamtomas raise intracranial pressure, with the progressive complications of that condition.

If birth injuries are excluded, the detection of subdural haematoma in the infant raises the suspicion of child abuse. Following early cases reported by Caffey(1947,1972), Guthkelch(1971) reported 23 cases from Hull Royal Infirmary. 98 of the subdurals had fractures, 13 did not. In 10 cases the lesions were bilateral. Five children had no marks of violence and no skull fractures associated with subdural haematomas. Guthkelch assesses the work of Ommaya, Haas and Yarnell(1968) on the mechanism of such intracranial injuries. He comments also on the domestic factors which predispose to harm being caused to these children, by the whiplash shaking effect. He emphasises in particular the need to look for other signs of abuse with great care, and in the child under two years to undertake a skeletal survey, which may show evidence of past injury both in the skull or elsewhere in the body(Caffey 1947 1972)

Imaging by CT Brain Scanning

Features of epidural and subdural haematomas on computerised tomographic scanning are quite different. A lenticular lesion is seen in the epidural haematoma, and a crescentic lesion in subdural bleeding. The mortality was estimated to be lower in epidural haemtomas as was the morbidity. When compared the location of subdural and epidural haematomas is significant. Supraentorial lesions are most commonly epidural, and almost always associated with a skull fracture. Subdural haematoma occurs less frequently in the posterior fossa, and is usually associated with a skull fracture. The source of bleeding is venous in these cases.

Exceptionally subdural haematomas may be arterial in origin, and result in substantial haemorrhage. They may present with the clinical features of an extradural bleed, and require urgent intervention. When this occurs the prognosis may be good.

Subdural haematomas are often associated with underlying cerebral damage. Whereas an extradural haematoma, treated early is not. Hence the good prognosis in the absence of delay.

Acute Intracerebral Haematoma

These lesions occur within the parenchyma of the cerebral tissue as a result of shearing forces, and are inevitably a complication of severe brain injury. Haemorrhage may also occur into a cerebral contusion, presenting as a delayed intracerebral bleed. Treatment is not necessarily surgical. Urgent CT scanning and neurosurgical advice is indicated.

Haematoma outcome

The advent of CT brain scanning has enabled earlier diagnosis of mass lesions, and operation when neurological status is more favourable. Unconsciousness, pupillary change and neurological abnormalities are associated with a less favourable outcome, and a number of authors have published their observations. The Glasgow Coma Scale may also be an indication of potential outcome. Cook et al(1988) has linked Glasgow Coma Score, CT scan features and pupillary responses, and produced an extradural score which is highly predictive. Clearly outcome is better if there are no associated primary brain or diffuse axonal injuries, or additional injury elsewhere.

Age influences outcome according to a number of reports. Children were said to have a good reuslt in 90% of cases, by Campbell and Cohen(1951). Jamieson and Yelland(1968) and McLaurin and Ford(1964). reported better outcomes under 20 years of age. By contrast Rivas et al(1988) found no difference. Dhellemmes et al(1986) reported a mortality of 9% under 15 years. Haematoma resulting from abuse has a poor outlook.

In almost all circumstances avoidance of delay in recognition, and urgent intervention offers the best prospect of optimal recovery. CT Scanning has modified the mortality and morbidity figures, by facilitating early diagnosis. Criteria for scanning varies, and must ensure no delay to neurosurgery, when undertaken outwith a neurosurgical unit.

9 Epilepsy

Early post traumatic epilepsy, a fit occurring within the first week following trauma has been reported in 2-6% of patients, in excess of that recorded in the emergency room. Early seizures occur more frequently in children than in adults and particularly in children under the age of 2 years(Jennett 1975 and Hahn et al 1988). The incidence in the very young child is disputed by Annegers et al(1980). It has been suggested that it might be due in part to child abuse cases. Children are more likely to develop epilepsy the more severe the head injury, as assessed by presenting coma scores(Hahn 1988). The severity of injury can be related to focal trauma, subdural haematoma, depressed fracture or cerebral oedema. Jennett had claimed that early epilepsy predisposed in childhood to late epilepsy, but this was refuted by Hendrick and Harris(1968) and by Annegers et al(1980). He also stated that the frequency was less in children than in adults. Early post traumatic epilepsy in children can occur after apparently minor head injury as was reported by Hendrick and Harris(1968). In the majority the fits occur in the first 24 hours and two thirds have more than one seizure.

The period of post traumatic amnesia, as well as focal injury, was believed to be a significant feature. Jennett(1975) reported a 12% incidence in all ages who were amnesic for less than 24 hours. Jennett reported that post traumatic epilepsy is five times more likely in the first year and three times greater five years after trauma than would be expected in the general population, at the same age. Beyond five years there was no significant effect.

When the causes of focal injury associated with the fits is examined Jennett(1975) advised that there was no benefit to be gained in relation to the epilepsy by elevation of a fracture. This presumably was because the injury to the cerebral tissue was sustained at the moment of impact, and was not a direct effect of the pressure of the skull fragment.

More recent work on the risk factors for late post traumatic epilepsy have been published by DeSantis et al(1992). They identified the risk factors for late post traumatic epilepsy, as defined by Jennett(1975), as early post traumatic seizures, depressed fracture, and intracranial haematoma. They noted that prolonged unconsciousness, post traumatic amnesia lasting more than 24 hours had been added subsequently. The authors sought to question the validity of these risk factors which were based on clinical data. They felt that precise definition of trauma severity and confirmation of the injury on CT, or surgically documented lesions of the brain substance were likely to prove risk factors.

They analysed a large number of patients, 4,831 adults, most of whom were not submitted to CT scans, 1,420 adults all of whom were admitted for CT scans and 3,302 paediatric patients aged between two months and 14 years. CT scans were available on only a few children.

A further group were selected to study the risk associated with impaired consciousness. 60 patients, 31 children and 29 adults were studied. These had all suffered immediate post traumatic coma, associated with diffuse brain injury and/or diffuse brain swelling.

All these patients had serial scans.

On the basis of their investigation they came to the following conclusions:-

The relevance for early post traumatic seizures appears to be different in children than in adults.

In the present series the prevalence of late post traumatic seizures was particularly high amongst children presenting with early post traumatic seizures. DeSantis' figures were even higher than those reported by Jennett and Hendrick(1975) and Harris(1968), all of whom accepted that early post traumatic seizures have been associated with all types of head trauma, but as expected have been higher in those requiring surgical intervention.

When early post traumatic seizures had a seemingly functional origin, the percentage of late post traumatic epilepsy has been much higher, than that observed in series without early post traumatic seizures.

DeSantis et al(1992) therefore confirmed the opinion that the observation of early post traumatic seizures in children, increase the risk of late post traumatic seizures.

75% of the adult patients who developed late post traumatic seizures had been subjected to surgery for traumatic intracranial haematoma. Moreover the prevalence of late post traumatic epilepsy was similar to that observed amongst patients, without early seizures, but with comparable severity and type of injury. The impression was that the brain lesion determined the risk of late post traumatic epilepsy, which did not require the occurrence of early seizures. The views of DeSantis et al(1992), were supported by the type and severity of anatomical brain disruption ascertained on CT scans.

In conclusion DeSantis et al(1992), believed that in adult patients early post trauamtic seizures are not a risk factor for late seizures per-se, but only if associated with documented focal brain lesions. This was also the view of Annegers et al(1980).

DeSantis et al(1992) further examines unconsciousness and post traumatic amnesia in its relevance as a predictor of late post traumatic seizures. They concluded that their evidence completely denied this association. The explanation offered was, that based on clinical factors alone, coma might have been regarded as severe brain injury associated with widespread cortical damage. In fact, as he had observed, loss of consciousness in brain stem dysfunction, need not necessarily be associated with epilepsy.

DeSantis et al(1992) concluded that early post traumatic epilepsy should not be considered as a risk factor for late post traumatic seizures in adults, whilst it seems to increase the risk in children. Prolonged unconsciousness, without focal brain injury, should not be considered a risk factor for late post trauamtic seizures. Focal brain lesions are the main risk factor to be considered in predicting late post traumatic seizures

10 Outcome

The child's brain has an age dependent vulnerability to trauma. Children less than one year have double the mortality compared to children between the ages of 1 and 6 years of age, and three times more than children between 6 and 12 years. This may be due to the water content, and poor myelination of the brain, with open fontanelles, and no fused sutures in the first year of life. Later with fused sutures, closed fontanelles and myelination the brain can better withstand trauma. 50% of infants with a tense fontanelle had a worse outcome than 5% with a soft fontanelle.
Outome is dependent on the nature and severity of the primary insult which is irreversible. It may range from a minor bump with full recovery, through to severe injury incompatible with life. Imposed on primary injury, may be secondary insults arising within the skull, or due to systemic effects. The prevention, control or reversal of secondary factors will be beneficial in influencing the ultimate survival or outcome. For this reason the meticulous recording of events, and effective resuscitation in the emergency room is important in assessing outcome.
Advances in CT imaging and its wider availability, and application to the minor injury group, have shown that changes can be detected on scans, which are not associated with obvious clinical or neurological features, at least initially. Recognition allows for follow up of these children, who may suffer learning, memory or emotional deficit. One of the problems is often the absence of a previous baseline for comparisons, and the child's limitation in expressing difficulties being experienced.
Outcome from severe injury is best anticipated by continuous monitoring of the level of consciousness from the first contact through resuscitation to intensive care. Many reports indicate that accurate scores are first recorded in the Neurosurgical Unit many hours after the trauma. Much useful research might come from precise earlier and frequent recording in the pre hospital and emergency department phase. The Glasgow Coma Score is the yard stick by which severe injury is measured. It is widely used to assess injury severity, and as a monitoring device, but also as a research tool which allows comparisons between different groups of patient in different centres and different treatment. Rimel et al(1982) has suggested that the scale should be subdivided to provide three categories of injury based on the level of the score, mild Glasgow Coma Score 12-15, moderate Glasgow Coma Score 9-11, severe Glasgow Coma Score 3-8. Patients with a Glasgow Coma Score of 8 or less are in deep coma. The gradation of the scale is well matched to outcome with increasing mortality with a falling score. Great care and judgement is required in the application to children. A minor head injury with a score of 14-15 may also be followed by sudden deterioration associated with a mass lesion. In childhood

cerebral swelling may be associated with sudden deterioration. For this reason Coma Scores have been developed specifically for children by Raimondi and Hirschauer(1984), Morray and Hahn et al(1988).

Secondary Insults

Delayed or secondary brain injury was examined by Miller et al(1979) and others to assess the contribution to outcome. There were highly statistical associations between the severity of the primary brain injury, the necessity for ICP monitoring, coagulopathy and subdural haematoma. Outcome was made significantly worse by secondary insults. Severe injury carries a mortality in the region of 33%. Vollmer(1993) produced an extensive review of prognosis and outcome in severe head injury.

Outcome Coma Score

The neurological assessment of patients following cerebral trauma, either in isolation or combined with other serious injuries, is an integral part of the duty of the emergency physician. Inevitably attention is focused on systems of assessment which assist in management decisions. The time scales are ideally confined to the first two hours following the examination. Resuscitation may lead to marked improvement. The energies of the Emergency Department are focused on ensuring survival, improvement and ultimate recovery.

The Accident Department however, is also the locus at which documentation of the initial clinical status may be of value in the later phase of decision making. The Glasgow Coma Score is well known and extensively used. The Glasgow Outcome Scale is less well known to junior doctors. All systems are designed primarily to allow the prediction of outcome from serious brain damage. It is of limited value to the emergency doctor as such patients are inevitably admitted to Intensive Care following resuscitation. Modifications include the Maryland(Salcman, Schepp and Ducher 1981) and LiegeScales(1985) and the Innsbruck Score. Severity correlated with amnesia was proposed by Jennett and Teasdale(1981), but does not apply to children.

When compared with adults, children have much lower incidence of mass lesions and whilst there is considerable speculation that this has an anatomical basis, it has not been proven. The outcome in the presence of a surgical mass lesion appears to be similar in both children and adults. Delay adversely affects outcome.

When the child has a combination of diffuse axonal injury, and a mass lesion the outcome is poor. Subdural haematoma, with its associated brain injury, has a less favourable outcome.

Children are more vulnerable than adults to post traumatic brain swelling. An extensive exposition has been published by Lobato(1993).

Whatever the pathology of the primary brain injury, secondary insults of hypoxia, hypovolaemia, anaemia and hypercarbia, seizures and uncontrolled intracranial pressure will unfavourably affect outcome(Mayer et al 1981).

The factors complicating injury in children compared with adults have been published by Alberico et al(1987).

The vital protective role of the emergency physician has been identified by Mayer et al(1985) and is discussed.

The pathology of failed treatment was exposed by Graham et al(1989).

Outcome depends on complex, multiple and interrelated factors across the wide spectrum of paediatric head injury, and a considerable time span in many cases.

11 Attendance Patterns

Authors presenting data on the epidemiology of head trauma provide valuable information on the incidence of head injury by season, day of the week and also time of attendance within the 24 hours. Such information complements the data relating to the injury incident. However like much of the information presented in epidemiology studies, comparisons may be difficult or valueless, in a wider context, when geographical variations and cultural activities vary considerably.

Adoleye, Obiang and Olumide(1976) reporting on 525 patients from Ibadan, the majority under the age of 10 years, noted a peak attendance on Sundays with domestic and motor vehicle accidents the common cause.

In their Pilot Study of Childhood Injuries, Klonoff and Robinson(1967), divided the children into two groups, those with scalp lacerations and those with symptoms of cerebral trauma. He found the rank order for seasonal visits was Spring, Summer, Fall and Winter for lacerations. For cerebral injury rank order was Summer, Spring, Fall and Winter. The day of the highest number of visits was Sunday, for both groups. There was a substantial drop on week days. Summer and Spring had the highest number of preschool attenders.

Klauber's(1986) study on Head Injuries in an entire community showed temporal variation. Excessive numbers attended at weekends, associated with motor vehicle accidents, with the maximum numbers on Saturday.

May produced an excess of victims, December and January were the lowest for attendances. The incorporation of children with adults makes any conclusion on this paper unsafe.

Kraus, Fife and Cox(1986) in an epidemiologal study from San Diego, California on children showed seasonal variations. There were more head injuries than expected in April, July, August and September, and fewer than expected in October and November. The variations by months was related to the number of falls. These authors found no difference by day of the week for either the occurrence or the severity of injury. The time at which injury most commonly occurred peaked in the afternoon and early evening.

Kraus(1986) extended his investigation to discover the interval from the time of injury to medical care. He found that children with serious head injury received treatment more promptly than those with minor head injury. Mode of transport was also examined and reported.

The hours of attendance were subdivided by cause, and variations between falls, recreation and motor vehicle injuries were shown.

Cordosa and Pyper(1989) investigated head injuries as a result of the use of off road vehicles. They had found there had been a progressive increase in the number of head injuries from these causes from 1980-1985. Dirt bicycles, three and four wheel all terrain vehicles can be used all year round, snow mobiles from November to April. The highest number of injuries occurred in the summer months. All occurred in daylight. The injuries for snow mobiles were highest in March.

Standards for the care of children in hospital were set more than 30 years ago by the British Paediatric Association(1985) and the Court Report(1975). Jackson(1985) wrote critically of the failure to implement the previous recommendations. The support of the then Casualty Surgeons Association was canvassed particularly in relation to children in Accident and Emergency Departments. This resulted in a Joint Document(1987).

The formulation of Guidelines for Adults following head trauma caused Heywood(1987) to note the deficiency of guidelines for the head injured child. He recommended that despite the views of the Royal College of Radiologists, skull xrays should be readily available for children following head trauma. Crouchman(1990) emphasised the importance of paediatric specialist input, and Brocklehurst(1987) recommended comprehensive care for the head injured child. This was directly relevant to the admission of children for head injury observations to the Neurosurgical Unit at Hull Royal Infirmary, whose A&E Department staff contributed to this Study.

In 1999 the Royal College of Paediatrics and Institute of Child Health, confirmed that the facilities and resources available do not meet the standards previously set, and are appointing an Intercollegiate Advisory Group to oversee their recommendations in the future.

The effects of any identified deficiencies on the outcome from particular illnesses or injuries was criticised. It was, however, conceded that resuscitation training courses, such as Advanced Trauma Life Support and Advanced Paediatric Life Support should have contributed to knowledge and expertise in the clinical field.

Information on paediatric head injury depends on the location in which the child is studied(Deane 1993). Inevitably most information has emanated from units treating severe injury. Patients in Accident & Emergency departments form the largest numerical group, but very limited prospective data makes comparison difficult. MacKellar(1989), and Mitchell(1994) have published reports. Comparison with adults have been made by the Glasgow group(Strang, MacMillan and Jennett 1978; Jennett 1990) and Brookes et al(1990). Attendances in urban Accident & Emergency departments are likely to reflect closely the incidence of head trauma, of any significance in the population served, and bear some comparison with epidemiological studiesKlauber et al 1981; Kraus et al 1986).

The male dominance in head trauma extends throughout the paediatric population, and has been confirmed by Burkinshaw(1960), Craft(1972), Annegers(1983), Klauber(1981), Kraus(1986), Boulis et al(1978), MacKellar(1989) and Mitchell(1994). In respect of the male dominance the child is similar to the adults.

Causes of Injury.

The child is more likely to be injured as a result of falls, and less frequently in road traffic accidents than in adults as reported by several authors. Unfortunately these reports include large numbers of admitted children(Alberico et al 1987). As the child advances in age, exposure to hazards modifies the causes, with bicycles and motor vehicle pedestrian injuries increasing, and these are the source of more serious head injuries.

The cause of injury which is unique to the child, is the form of assault known as baby battering. Although adults suffer head injury due to malicious attacks, the pathological features of the abused child, have no match in the adult. The condition occurs mainly in infants. Choux(1996) has described a maximum incidence of 31% in children aged 6-12 months, 4% under two months, 17% 2-6 months, 22% 12-18 months and 26% 18-24 months. These figures do not reflect Accident & Emergency attendances for which data is not available. The condition carries a high mortality. Head injury is the main cause of death in 30%,(Shapiro1983)

Skull Fractures

Infants are occasionally found to be anaemic on presentation. This is the result of blood loss in an extracerebral haematoma, which decompresses via a skull fracture and presents as a scalp swelling, Choux(1996). In all other circumstances, as in the adult patient, alternative causes of blood loss must be sought in the presence of significant trauma. The presence of a skull fracture has differing implications in the different ages of children, than in adults. In infants and children under the age of two years, the skull is thinner, and the sutures are not fused. The fontanelles close progressively up to the age of two years. The skull is more readily fractured, by the same degree of force, than the adult skull. Subcutaneous haematoma often overlies the fracture in childhood. The location of the fracture and its characteristics may provide clues as to the cause, mechanism and potential for complications. The incidence of skull fracture varies from 1-3% in the emergency department, to 80% in the neurosurgical unit. The linear fracture is most commonly caused by falls 75% to 85%(Choux 1996). The features of fractures have significance, relevant to the underlying cerebral injury or complication.

Linear fractures are most common infancy and childhood. They are usually simple, and extend from one suture to another, and are most common in the parietal area. Diastasis of a suture associated with a fracture, occurs in the young child. The appearances of linear fractures vary with age. There may be wide separation in the youngest children, and this is an indication for extended follow up. Choux has identified location or site of fracture in individual age groups in childhood. Fractures have a high incidence in infancy, and it may be complicated by a growing fracture and leptomeningeal cyst formation.

Depressed Skull Fractures

The incidence of depressed fractures varies widely in reports, most of which arise from neuro surgical units - 7.5% to 25%. In emergency departments the incidence is rare 0.18% as in this Study. In the Neurosurgical Unit where the majority are, of necessity referred, 40% - 50% of depressed fractures occur in children, mostly in the 4-8 year age group. Depressed fracture is also common in infancy. The characteristics of the infant skull make depression more likely, but most of the depressed fractures are closed. Birth trauma is a cause, in neonates.

The treatment of depressed fracture is at the discretion of the neurosurgeon. Jennett(1975) stated that intervention did not reduce the incidence of epilepsy, in contrast to Choux(1996), who claimed a lower rate, because of an aggressive routine surgical approach to management. In children the risk of infective complications is substantially lower than in adults, as fewer are compound, and this relates to the higher incidence of assaults in adults.

The child, compared with the adult particularly in the first six years of life, is at greater risk of penetrating injuries, because of the physical characteristics of the skull.

Over the years of the debate regarding the alleged excessive use of skull xrays, there was no apparent attempt to seek information from those requesting the films. It might be argued that solutions to the problem might have been achieved earlier, if the doctors were persuaded that their requests were excessive, their reasoning flawed and that the options being recommended met their reasonable anxieties. The problem was addressed in 1980 by Cummins. He noted that after the introduction of high yield lists 80% of skull xrays were taken in patients who did not meet the defined criteria. Cummins postulated that doctors did not reject the recommendations for perverse or irrational reasons. Rather they ordered them for a variety of reasons carrying credibility and logic.

Using a research interview method Cummins(1980) identified several reasons for the alleged over usage. Fifteen emergency service doctors were interviewed. The interview comprised a three part questionnaire, case simulation and discussion of head injury problems. The respondents produced good reasons overriding indications, problem solving strategies, decision making, fear of uncertainty and established routines amongst their reasons. These were examined in greater detail. Cummins concluded that request for xrays are not made on absolute indications, but are highly discretionary. Attempts to apply protocols produced evidence that the requests were not necessarily based on patient characteristics. When faced with recommendations from remote Radiologists, clinicians disagreed with the criteria. This was not perverse non compliance, but a disagreement over proper indications. Cummins found that problem solving strategies generated most requests. Clinicians demonstrated a surprising strategy flexibility, which varied between patients. They may be a reflection of clinical inexperience.

Gleadhill et al(1987) reported in the British Medical Journal on the use of xray examinations in a busy urban Accident & Emergency Department. In a study of 5,463 x-ray examinations, they discovered that Casualty Officers whilst in post did not become more selective in their requests for xray. Their ability to interpret the films however improved. 4.9% of trauma radiographs were misinterpreted. One in four of the errors was clinically significant. Clinical guidelines for selective radiography produced significant and sustained reduction in the number of x-rays requested. They concluded that the number of requests can be reduced by using guidelines, and that this did not compromise the quality of patient care. This had the advantage of appreciable savings both in the patients waiting time and the expenditure on diagnostic imaging.

The 12 doctors who entered into the study were all of Senior House Officer Grade. Although the majority had come from their post registration appointment, the overall level of experience in this Speciality was considered uniform across the group. In the Accident & Emergency Department Gleadhill et al(1987) had noted an upward trend in the number of patients referred for xrays between 1982 and 1985, an increase from 51% - 59%. Following the institution of the Study being reported the referral dropped to 48% overall. 65% of the new attenders were due to trauma, 65% of these were xrayed. 24% of the radiographs were positive i.e. showed a relevant abnormality.

A study of the patients who were subject to skull xrays was of interest as the paper implied the acceptance of guidelines. Following an introductory course and instruction at weekly seminars, together with special attachments, one of which was to a consultant radiologist, 696 patients who had attended with head injury were examined. 384 were xrayed. Seven fractures were detected, representing a yield of 1.8% of the films. Two false positive interpretations were made but there were no false negatives. Total errors as a percentage of the radiographs had been reduced to 0.5%.

In their discussions the authors considered the factors which had been associated with increasing workloads in xray departments, originating from Accident & Emergency Units. They related this to changing expectations of patients and the threat of litigation It was noticed that whilst the number of new patients between 1982 and 1985 was increasing, the proportion of patients referred for xray increased more significantly. It was concluded that clinical experience alone did not influence positively the ability of the doctors to select patients for radiography. In fact their skill deteriorated slightly. Their clinical experience with trauma, in addition to a teaching programme, positively influenced the abilities of doctors to interpret the xrays correctly. Clinical guidelines on selection for x-ray with certain injuries reduced the overall x-ray rate. Gleadhill et al(1987) quoted DeLacey(1979) who had found that 7% of x-rays were incorrectly interpreted, and Wardrope and Chenells(1985) 6.2% misinterpreted. The error rate of the Accident & Emergency Department under review was 4.9% compared with Swains(1986) 3.9% for trauma alone. Clinically important error occurred in 1.2% compared with Wardrope and Chenells(1985) 1.1%. The authors concluded that problems with interpretation of skull x-rays emphasised the need for adequate instruction both in the application and the interpretation of skull radiographs. This would lead to more appropriate management decisions.

It has perhaps been assumed that junior doctor errors in the interpretation of skull films will be made out of hours, when a second opinion may be unavailable. Vincent et al(1985) assessed 505 radiographs taken at night and week-ends. The Senior House Officers interpretation at the time was compared with that of a radiologist subsequently. Vincent et al referred to previous studies and confirmed the importance of comparing like with like. The most important statistic is that which identifies the missed abnormality from amongst the abnormal films, rather than from the total xrays taken. This is the definition which has been used in this Thesis, i.e. the false negative. It is that area which should be further examined to discover whether the error rate could or did affect the patient's management.

In Vincents'(1985) study 35% rate of error was noted and 39% of these errors were significant. The rates varied from different areas of the body but there were 60% from skull xrays. This showed that a patient with a skull fracture out of hours in a London Teaching Hospital had a greater than even chance of having his skull fracture missed by an unsupervised Senior House Officer!! Individual doctors varied in their rates of error, but it was not statistically significant. It might be believed that Senior House Officers would improve over the six month tenure of their posts. As Swain(1986) showed, there was improvement in selection, but no improvement in the interpretation and this proved to be so in Vincent's Department. There was evidence of no overall improvement, and no change in individual doctors performance.

Vincent et al(1985) discusses the possible remedies. Clearly doctors do not pick up abnormalities as they go along with their working experience. The system to date at that time did not appear to contribute to improved performance. Since then more formal teaching programmes have been instituted.

The formulation of Guidelines by experts in this particular field is to be commended. That must not however provide a false sense of security, or the assumption that the advice is disseminated to those who require it, or that it is subsequently implemented.

Delamothe(1993) had addressed the concept of guidelines in general terms, claims that they were "systematically developed statements which assist in decision making, about appropriate health care for specific clinical conditions". They were regarded a general statement of principal, as opposed to protocols providing a more detailed application. He stated the problem was not terminology, but implementation. He suggested that the guidelines were suspect as they standardise practice around the average, which is not necessarily the best. Innovation may be stifled. Deviation from the guidance might have medicolegal implications. The author noted the fundamental role of the doctor, and the right to exercise judgement. He stated that guidelines should be developed by those who would be using them, and accepting responsibility for the results. Their implementation, he suggests, would be more difficult than their preparation. Implying that money is saved in this way, he stated that in certain circumstances money may be required for development and implementation. The points raised in his paper have been examined in this Thesis, particularly in relation to doctors practices.

A recent view of the preparation and use of Guidelines has been published by Thomson(1999). In order to examine the current practice of Senior House Officer in an adult/paediatric unit, Monklands District General Hospital and the same grade doctors in an exclusively paediatric unit, the Royal Aberdeen Childrens Hospital, the Author prepared a questionnaire. This was submitted on a one to one basis to all the doctors at interviews. The results are reported under "Why doctors request skull xrays"

F.

RESULTS SUMMARY

STATISTICAL ANALYSES

AND

CONCLUSIONS

1. AGE AND SEX

1.1. Introduction

The age of the child is an indication of the general and cerebral development. The effects of head trauma are modified as a consequence, and vary not only from adults, but from children at different ages.

The age and the sex of the child who sustains a head injury may reflect the activity, which he/she is capable of undertaking, the environment in which the activities are pursued and the dangers encountered. Causes and mechanisms of injury are, in part, age related, as is the severity of cerebral trauma and outcome.

Conversely age may protect the child from injury, the infant being limited in mobility may be less at risk, but also more dependent on its carer.

The management decisions in the A&E Department may be influenced by age. The resources required may be modified by the special needs of the child.

Information acquired from the data, may in addition have implications for accident prevention in vulnerable groups.

1.2 Summary of Results

Age

The highest incidence of head injury occurred in the preschool children, 45%, with primary school children 39%.

Infants have the lowest incidence 8%.

The figures for the 12-14 are lower at 8%, because this group is under represented in the paediatric A&E Departments.

Sex

Male children, 66% are twice as likely to sustain head injury as female, 34%, and the male dominance extends to infants 55%. Male dominance increases proportionally with age.

Similar patterns are seen across all the hospitals for male sex.

Skull Fracture/Age/Sex

There were 102 confirmed vault fractures and 9 clinical base of skull fractures, one of which was confirmed. When the incidence of vault fractures is examined the vulnerability of the infant skull is confirmed 25/102 fractures.
7.7% of both males and females.

The incidence of skull fracture is lowest in the preschool children.

Skull fractures in the 12-14 years old was 4% in the males and 2.3% in the females. This perhaps reflects more forceful injury, as judged by fracture, in the older males.

Age and Sex - Univarate Analysis

Risk of Fracture by Age

The probability of a child presenting with a head injury resulting in a skull fracture was found to be dependent on the age of the child (chi-square 47.4, df=3, p<0.0005). In particular infants (under one year) had substantially more fractures than expected.

The number of children in each age group with skull fractures, and the expected number under a hypothesis of independence has been calculated (see Appendix J)

When children under one year are compared directly to the other subjects they demonstrate a significantly higher risk than older children (chi-square 39.6, df=l,p<0.0005)and have an odds ratio of 3.8 (CI=2.4, 6.0).

The odds ratios are (95% confidence intervals) for each age group :

< 1 year	3.8	(CI 2.4, 6.0)
1- 4 years	0.47	(CI 0.30, 0.72)
5-11 years	0.86	(CI 0.53, 1.21)
12-14 years	1.79	(CI 1.01, 3.17)

Therefore a child under one year with a head injury is almost four times more likely to have sustained a skull fracture than an older child.

Male Dominance

Significantly more than half the children presenting with head injury at the six centres were male (one-sample t-test, HO: proportion of males = 50%, t=19.4, df=5, p<0.0005, 95% CI=(64%, 68%).

The Risk of Fracture by Sex

The analysis is based on 102 vault fractures confirmed by radiologist and nine clinical base of skull fractures, one confirmed radiologically.

The probability of a child presenting with a head injury resulting in a skull fracture was found to be independent on the child's sex (chi-square = 0.219, df = 1, P = 0.64).

The expected and observed numbers of skull fractures by sex (under HO: skull fracture is independent of sex). This result is shown both in children under one year of age (chi-square = 0.0303, df=1, p=0.582) and in children over one year (chi-square = 0.08, df =1, p=0.778.

1.3 Conclusions

1. The higher incidence of injury in male children is confirmed and includes infants and increases proportionately with age.

2. The probability of a child across all age groups having sustained a skull fracture was found to be independent of sex.

3. Risk of skull fracture was found to be dependent on the age of the child. Infants have substantially more fractures than expected.
   The univarate analysis supplied takes no account of causes and mechanism of injury or of symptoms and physical signs.

4 Infants should be assessed with particular care. Children under one year are almost four times as likely to sustain a skull fracture, than the toddler and primary school group. There should be a liberal policy with regard to skull xray,in infants. The circumstances of "the accident", and the radiological features should be evaluated to exclude abuse, in children under two years of age.

5. Skull fractures in infants are occasionally followed by complications, including a growing fracture, not seen in older children.

6. Depressed fracture may only be seen on skull xray when not previously suspected clinically whether in the presence or absence of a scalp wound, and is an indication for skull xrays, with special views if required.

2. CAUSES AND MECHANISMS OF INJURY

2.(a).1 Introduction

The cause of injury, will be influenced by the stage of development and the mobility of the child. Infants are dependent on parents or carers. Injury when it occurs may reflect lack of care or deliberate harm.

Increasing mobility without good physical control and co-ordination, may result in falls in toddlers. The older child is increasingly exposed to new risks, as the home is exchanged for an expanding environment. Greater agility, inquisitiveness and reduced supervision increases the potential hazard. Exposure to vehicular traffic, and inexperience adds to the danger. Trauma to the head in childhood is the result of the introduction of a variety and combination of factors. The toddler and the young child, falling within a distance approximate to his or her height on to a surface is a frequent occurrence. The result is often a minor head or even just a scalp injury. At the opposite end of the causal spectrum are the injuries resulting from high velocity impact forces, from contact with motor vehicles, cycle accidents and falls from a height. The cause of an injury, also affects the mechanism, when force is applied to the skull and intracranial contents. Inevitably there are interactive effects. For the purpose of the Study, however, the causes and the mechanisms, as defined were recorded separately.

The causes were defined as Falls, Road Traffic Accidents and Assaults, including Non-accidental Injury - N.A.I. or Child Abuse.

2 (a) 2 Summary of Results – Causes of Injury

In childhood, falls proved to be the most common cause of injury	4934	82.4%
Road Traffic Accidents resulted in	354	6%
Assaults	547	9.5%
Children head injured as a result of proven abuse	22	0.4%

The number of falls as a percentage of all the causes show:

Home	46%
Play/sport	29%
School	9%

The children who sustained head injury as a result of falls had the location identified:

Home	54%
Play/sport	34%
School	11%

The figures suggests school offers a degree of protection as a supervised and disciplined environment.

Road Traffic Accidents

When the Road Traffic Accidents, 6% of all the causes are examined, children were injured as:

Pedestrians	2.8%
Occupants	1.6%
Cyclists	1.7%

The proportion of Road Traffic Accidents seen in the Accident & Emergency Departments is significantly less than those seen in Neurosurgical Units, Intensive Care and inpatient beds, where the most serious injuries are treated.

It was of concern that 75% of the children injured as occupants were not restrained by safety belts or seats.

Children who travel as occupants are passive victims, dependent on adults for their safety and protection. As they become more active and independent, they may contribute to the accident. This may be due to lack of awareness of danger, inexperience and immaturity. In a hostile environment they are at risk for the activities of others including adults.

The relationship of the age of the child to injury as a consequence of a Road Traffic Accident is shown in, Table 2(a)(vi).

When assault and non-accidental injury is examined, risk increases with age, Table 2(a)(1)(vii).

Skull fracture and Cause of Injury

Falls	The commonest cause of childhood injury resulted in skull fracture in	1.5%
Road Traffic Accident	Produced skull fractures in	5.0%
	with Pedestrians at greatest risk	7.5%
	and Cyclists	4.1%
Assault	Resulted in Fractures in	0.1%
	whilst Non Accidental Injury was associated with	9.1%

(Table 2(a)(vii))

Fracture frequency for all causes is shown in Table 2(a)(viii).

When causes are related to scalp injury and fracture the results are shown Tables 2(a)(ix-xiii).

Cause/Fracture – Tables 2(a)(ix-xiii)

When the frequency of fracture is related to the cause of injury it is seen that falls, the largest numerical group, has the lowest fracture rate, in the Emergency Department.
Road Traffic Accidents, particularly those involving child pedestrians and cyclists has the greatest incidence of fracture.

The identification of Road Traffic Accidents as a cause of more severe head and cerebral trauma in childhood is likely to prompt Casualty Medical Officers to request skull xrays - in this group of patients.

The low incidence of fracture in the larger number of children, who fall may provide an opportunity to reduce the number of requests for xrays. The cause will not be the only factor influencing the doctor.

The scalp injury feature, the site of the impact and the mechanism may need to be taken into account as may symptoms and neurological signs.
It has been suggested that the nature of the scalp injury resulting from a particular cause might influence the casualty medical officers decision to request skull xrays. The cause

of injury, be it a fall or a category of road traffic accident might result in a scalp injury with a higher or lower risk of skull fracture. The cause of the injury, was examined in relation to the nature of the scalp wound sustained and the age and incidence of skull fracture.

Scalp Feature/Cause/Skull Fracture – Tables 2(a)(ix-xiii)

When the causes of injury were examined in all age groups, the absence of any recorded scalp feature was noted in 868 children, seven of whom sustained a skull fracture, 0.8%. The presence of swelling of the scalp was noted in 1,685 and 57 fractures were detected. The incidence was highest in children hurt in road traffic accidents, followed in frequency by falls in sport/play and at home. The vulnerability of the infants skull is again demonstrated where 14/17 fractures resulted from falls 3.4%.

Abrasions and contusion of the scalp was recorded in 961, with 22 fractures, 2.3%. The incidence was highest in the road traffic accidents followed by falls.

The short superficial lacerations, a large group, 2342 revealed only nine fractures, 0.4%. It was not recorded in road traffic accident trauma. The highest incidence of fracture was recorded in child abuse.

The long superficial lacerations of which there were 40 had no fractures detected from all causes.
The deep short lacerations of which there were 62 had three fractures only two due to assault and one, a fall at play/sport 4.6%

The deep long lacerations 15, revealed four fractures 21% resulting from falls and a pedestrian road traffic accident.

Superficial lacerations are confirmed as being rarely associated with skull fracture, whatever the cause of injury only 0.4% of cases. It forms a large group, in the majority of which requests for skull xrays could be reduced, whatever the cause with very low risk of missing a fracture. The suspicion of a foreign body may justify examination however.

The presence of galeal laceration is indicative of more significant trauma, with fracture present in 4.6% and 21.1% of cases. The clinical features justify the skull xrays, whatever the causes identified. Assault, with its focal impact, may result in a depressed fracture. Skull xray best demonstrates this type of fracture though specialised views may be required.

It must be remembered when there is a breach in the scalp, a foreign body may be present. Skull xrays are the most reliable means of detecting opaque foreign material. Long superficial wounds might be amenable to exploration, but in the young child, under local anaesthesia, the procedure may be difficult. Xray by locating the foreign body can also facilitate and confirm its removal.

Statistical Analysis

Skull Fracture - Cause of Injury

The probability of a child presenting with a head injury resulting in a skull fracture was found to be dependent on the Cause, (chi squared = 57.0, df=7, $p<0.0005$). In particular pedestrians involved in a road traffic accident had substantially more fractures than expected.

The number of skull fractures by each cause, and the expected number under a hypothesis of independence is shown, (Appendix J).

When children involved in a road traffic accident (either as an occupant pedestrian or cyclist) are considered as a group, and compared directly to other subjects they demonstrate a significantly higher risk of skull fracture (chi-square = 26.9, df=1,$p<0.005$) and have an odds ratio of 3.5 (C.I. = 2.1,5.9). Therefore a child presenting with head trauma after involvement in a road traffic accident is more than (3) three times as likely to have a skull fracture, than from another cause.

Children whose injury was identified as assault, NAI, child abuse, also resulted in a higher risk of skull fracture, than from other causes. (Chi-square = 6.5, df=1, p=0.011) and have an odds ratio of 5.4 (C.I. – 1.3, 23.5).

When the causes of injury and the sex of the child are considered, more male than female children sustained head injury for all causes.

Cause and Sex

The cause of injury was found to be dependent on the sex of the child, (chi-squared = 71.445, df=7, p<0.0005), with males being more likely to present after a road traffic accident as a cyclist and after an assault.

The expected and observed number of patients by sex and cause of injury (under H.O. is shown in (Appendix J)

The odds ratios and 95% confidence intervals for each cause of injury and fracture are:

	Odds Ratio	C.I.
RTA Occupant	1.19	(0.29, 4.91)
RTA Pedestrian	4.73	(2.54, 8.81)
RTA Pedal Cycle	3.04	(1.21, 7.63)
Assault	0.67	(0.31, 1.45)
Fall at School	0.38	(0.14, 1.03)
Fall at Home	0.48	(0.32, 0.73)
Fall Sport/Play	1.70	(1.15, 2.50)
Assault/NAI	5.43	(1.25, 23.54)

2.(a).3 Conclusions

1. The probability of a child presenting with a skull fracture following a head injury was dependent on the cause of injury. Road Traffic Accident pedestrians had substantially more fractures than expected.

2. The cause of injury was found to be dependent on the sex of the child, male children being more likely to present, as a cyclist, injured in a road traffic accident, and after assault. This may reflect the activities in which males engaged, and a more aggressive approach.

3. Falls, the largest group, produced 73 skull fractures, the largest number at sport/play and the lowest at school.

4. Non-accidental injury, had the highest incidence of skull fracture for all causes.

5. The cause of injury has been shown to influence the doctors decision to request skull xrays. This is justified unless the criteria for CT Scanning is met.

6. When the cause of injury is matched to the features of the scalp injury, it is shown that the cause of injury likely to produce a skull fracture are most commonly associated in children with scalp swelling and contusions and galeal lacerations.

2.(b) Mechanism of Injury

2.(b).1 Introduction

The biomechanics of head trauma is influenced by a wide variety of factors the size of the object, in this case the child's head, the contact surface, the velocity, kinetic energy at impact, deceleration and stopping time. Measurements can be made experimentally for the skull, but not for the intracranial contents.

Kinetic energy can be absorbed on impact by deformation of the skull with or without fracture(Popvic, Klun and Noe 1994). When transmitted to the intracranial contents a complex range of injuries occur. When falls and blows to the head are compared in experimental models the same force may produce different patterns of injury, falls "countercoup" and blows, "coup" damage.

The pathology, which results from trauma to the head and brain, is the consequence of the interaction of many factors. In children the history of the event may be unreliable, because of the age of the patient, and the absence of adult witnesses. In this Study I sought to recover information on the contact surface with the head, and the impact forces applied. It was not possible to recover accurate information on the velocity, except in the minority of motor vehicle accidents, where expert assessments were available in police reports. There was inevitably close interaction with causation of injury. The data is shown in Table 2(b)(iii) Mechanism of Injury from the definitions previously defined.

The term mechanism was used to identify forces applied to the head, and the characteristics of the contact surface or agent. This was relevant to the experimental models, relating the pathophysioloical responses to the forces applied locally or diffusely to the head.

Collecting the information in the paediatric patient proved difficult in some cases where the accident was not witnessed, or the information proved unreliable.

2.(b)2 Summary of Results – Mechanism of Injury

The commonest mechanism of injury recorded in the Study was:

Falls onto a hard surface	2,955	46%
Followed in frequency by:		
Bumps on a hard surface	846	14.2%
And		
Struck with a blunt object	580	9.7%

Table 2(b)(xix)

The injury sustained will depend on the velocity. The majority of falls were within the patient's own height and therefore of low velocity.

In blows with blunt objects it was impossible to know the velocity.

It was surprising that 3.4% of falls occurred onto a soft surface, but accounted for 60% of the requests for skull xrays and produced two fractures, one in an infant ? abuse.

Sharp object impact produced the lowest request for skull xrays – Table 2(b)(ii).

The impacts from blunt trauma and hard surfaces produced 93/102 vault fractures.
18 occurred in infants.

More fractures proportionally from hard blunt trauma occurred in the 12-14 year olds – Table 2(b)(iii).

By contrast sharp injuries produced only five fractures.

The fracture frequency from each mechanism is shown Table 2(b)(iv).

The figures suggest that injury resulting from a sharp mechanism, might justify a reduction in requests for skull xrays. Some injuries do however produce incised wounds, which carry the risk of penetration, and the chance of a retained foreign body, which skull xrays would identify. This group does allow the doctor a discretionary approach which was confirmed. It requires full evaluation of other factors operating at the moment of injury.

Mechanism of Injury – Univarate Analysis

The probability of a child presenting with a head injury resulting in a skull fracture was found to be dependent on the mechanism of the injury (chi-square = 30.8, df=6, $p<0.0005$).

In particular children falling, bumping on or being struck with a sharp object had substantially less fractures than expected.

The number of skull fractures by each mechanism and the expected numbers under a hypothesis of independence is shown (Appendix J).

When children have suffered a sharp injury are compared against other subjects, they demonstrate a significantly lower risk of skull fracture (chi-square = 16.8, df=1, $p<0.0005$) and have an odds ratio of 0.19 (C.I. = 0.08, 0.46). Therefore a child presenting with a head injury after sharp injury is about a fifth as likely to result in a skull fracture than other mechanism.

The largest group of head injured children sustained blunt trauma on hard surfaces.

Sex – Mechanism of Injury

The sex of patients presenting with a head injury, was found to be dependent on the mechanism of injury. In particular males were more likely to present after being struck with a blunt object than females (chi squared = 32.10, d.f. = 1, $p<0.0005$) and females are more likely to present after a fall to a soft surface (chi squared = 5.75, d.f= 1, p=0.0016).

The odds ratios and 95% confidence intervals for each mechanism of injury are:

	Odds Ratio	C.I.
Fall to soft surface	0.52	(0.13, 2.12)
Fall to sharp edge:	0.26	(0.10, 0.71)
Fall to hard surface:	2.73	(1.79, 4.17)
Bump against sharp edge:	0.11	(0.02, 0.79)
Bump against hard flat surface/s:	0.68	(0.36, 1.26)
Struck with blunt object/s:	1.15	(0.63, 2.10)
Struck with sharp object/s:	0.98	(0.98, 0.99)

The higher risk of all types of hard, blunt trauma resulting in a skull fracture is confirmed statistically

2.(b).3. Conclusions – Mechanism

1. The probability of a child presenting with a head injury resulting in a skull fracture was found to be dependent on the mechanism of injury

2. Children who have sustained their injury as a result of hard blunt impact have a higher risk of skull fracture than other mechanisms.

3. The influence of sex on the risk of skull fracture and the mechanism of injury shows males at greater risk of blunt trauma and assault.

4. Children who sustain head injury as a result of sharp impact injuries have a significantly lower risk of skull fracture, but penetrating injuries need to be excluded.

5. It was surprising that any fracture resulted from impacts on soft surfaces. This raises the question as to the accuracy of the history, and the possibility of abuse.

6. Sharp impact injuries have a low incidence of skull fracture. A child presenting with this mechanism is one fifth as likely to have a skull fracture as any other mechanism.

7. When the mechanism of injury is a sharp contact, and this is related to the features of the scalp wound, ie. superficial laceration, and its location or site on the skull, e.g. frontal, and the risk of fracture calculated, a significant reduction in the requests for skull xrays could be achieved at minimal risk (see results – Scalp Wounds and Site of Injury (Section 4). This knowledge may allow a substantial reduction in skull xrays, with minimal risk to the patient, other factors considered.

3. COMA AND LOSS OF CONSCIOUSNESS

3.1 Introduction

Consciousness is a state which is difficult to define, but which is recognised by meaningful interaction by a person with his or her environment. Consciousness involves a complex interaction, between the cerebral cortex, subcortical structures including the hypothalamus and brains stem centres. Disconnection of the structures at any level results in alteration of the conscious state. The wakeful state requires an activation of the ascending reticular system to be projected on to both cerebral hemispheres, via the hypothalamus and the diecephalic centres directly or indirectly. The reverse process from the cerebral hemispheres to the brain stem is necessary for the conscious state.

It follows that consciousness may be impaired by a severe primary trauma to the cerebral hemispheres, as occurs in diffuse axonal injury, resulting in disconnection to the brain stem centres. The latter may be compressed as a consequence of raised intracranial pressure produced by a supratentionial mass lesion. There may, following severe trauma, be dysfunction at both cortical and brain stem level as a consequence of impact, disruption and haemorrhage.

The level of consciousness, and the extent of cerebral dysfunction is a manifestation of the severity of brain injury, both primary and secondary or a combination of the two.

The spectrum seen clinically following head trauma ranges from mild cerebral concussion syndromes, where consciousness is maintained, but there is evidence of temporary neurological impairment, to the condition of deep coma associated with diffuse cerebral injury. Where the anatomical disruption is widespread, the condition is incompatible with life. Between the extremes of the spectrum are varying degrees of diffuse axonal injury. The most mild degrees of diffuse axonal injury result in coma lasting beyond six hours. The moderate to severe injury results in extended periods of coma from days to months or even years.

Superimposed upon the diffuse white matter shearing, which results in loss of consciousness from the outset, are the effects of secondary insult, which may further impede recovery or accelerate deterioration.

In the Accident & Emergency Department, coma is by definition, a serious and life threatening emergency. It warrants urgent and aggressive intervention to support the injured brain. The primary injury cannot be reversed. Nevertheless it is essential that the damaged areas of the brain are protected from the secondary and preventable insults which once set in train are difficult to reverse, and trigger a cascade of pathological, physiological and biomechanical responses which may result in a recoverable primary injury being converted, as a consequence of intracranial hypoxia, anaemia, ischaemia, seizures and hypovolaemic shock to a disastrous or fatal outcome. It might be expected that aggressive management of the seriously injured might result in increasing numbers of profoundly disabled survivors who might otherwise have died. This has proved not to be the case in children.

3.1 Summary of Results

In the Accident and Emergency child population attending following head trauma, 5993, there is a very small number, 7% within a large group, whose clinical assessment will require an ongoing Coma Scoring System. It is, however, essential that a base line is established on arrival so that deterioration can be detected early and its significance appreciated.

In this Study from the total 5993:

	N	%
No history of Loss of Consciousness	5581	93.0
Loss of consciousness for more than five minutes and recovered	335	6.0
5–30 minutes fully recovered	35	0.6
30-60 minutes impaired	3	0.1
> 60 minutes – remains impaired	25	0.4

Guidelines in the participating hospitals varied. In three units, including both of the Paediatric Hospitals, admission was mandatory if any history of loss of consciousness had occurred. This was regardless of the confirmation of full recovery at the time of attendance.

There is still controversy about whether admission or CT scanning is the appropriate next step. In the absence of significant symptoms and signs, CT if negative might allow discharge home with head injury instructions.

Scanning may be difficult in the uncooperative child, who may require sedation. Admission may be a safer option, though in a minority CT may be indicated by skull fracture or deterioration

Teasdale(1990) has identified the risk of haematoma in the presence of impaired conscious level, with and without skull fracture, but not all accept his view that all children should have a CT Scan.

This Study has shown that a history of loss of consciousness of whatever length carries a greater risk of skull fracture, than when there has been no impairment of consciousness, or amnesia.

3.3 Loss of Consciousness/Skull Fracture – Univarate Analysis

The probability of a child presenting with a head injury resulting in a skull fracture was found to be dependent on whether a history of loss of consciousness or amnesia was noted, (chi squared=199.5, d.f.=4, p<0.0005). All categories of unconsciousness and amnesia had more fractures than expected.

The number of fractures of the skull by length of unconsciousness and the expected number under a hypothesis of independence is shown, (Appendix J).

When all children with a history of unconsciousness or amnesia (regardless of length) are considered as a group and compared directly to other subjects, the demonstrate a significantly higher risk of skull fracture, (chi squared = 65.1, d.f..=1, p<0.0005) and have an odds ratio 5.2(C.I.=(3.3,8.0).

Therefore a child presenting with any history of unconsciousness or amnesia is five (5) times more likely to result in a skull fracture than children with no history of unconsciousness or amnesia.

The sex of patients presenting with a head injury, was found to be independent of a history of unconsciousness (chi squared = 5.25, d.f. = 4, p = 0.263). (Appendix J).

This would justify skull xrays being requested, if the criteria for immediate CT scanning are not already met. It would include the child with a coma score of 15/15 at risk of developing an intracranial haematoma, without significant symptoms, and also the increased risk of intracranial injury requiring evaluation, who may not have a mass lesion.

3.3. Conclusions

1. Loss of consciousness is rare in the Accident and Emergency Department population of children who have sustained a head injury.

2. Any history of loss of consciousness of whatever length is associated with five (5) times the risk of skull fracture, than those who have not lost consciousness. The child in coma in the A&E Department, has 35 times the risk of skull fracture.

3. The sex of patients presenting with a head injury was found to be independent of a history of loss of consciousness.

4. This confirmation of risk would justify requesting skull xrays in these patients, unless they already fulfilled the criteria for CT scanning.

5. The request for skull xrays is justified in those children who have a Glasgow Coma Score of 15/15 in the A&E Department, but who are at risk of developing an intracranial haematoma. This would be particularly valuable in the child at risk of extradural haematoma. Some of these patients will present in the "lucid interval". They may have no clinical signs or symptoms, but fall into Teasdales(1990) category of higher risk, if a skull fracture is identified. This would expedite CT scanning before deterioration had occurred. The identification of a skull fracture has also been identified by both Lloyd et al(1997) and Quayle et al(1997) as increasing the risk of non-neurosurgical intracranial injury. Knowledge of such injury will influence management.

4. SCALP INJURIES AND THE SITE OF SKULL TRAUMA

4.(a).1. Introduction

An injury to the scalp, in the form of a laceration, abrasion, bruising, swelling or loss of tissue is confirmation of trauma to the head. It is the commonest manifestation of head injury, particularly in childhood. The nature of the scalp injury may provide clues to the potential for complication, including associated skull or intracranial damage. An understanding of its anatomy, and its role is essential to decisions of management in large numbers of cases in the Accident & Emergency Department. Rarely Specialist skills are required when avulsion or extensive tissue loss or damage has occurred.

ANATOMY OF THE SCALP

The anatomy of the scalp can be learned from a study of text books of anatomy. The scalp consists of five layers - skin, subcutaneous tissue, the scalp aponeurosis or galea, the subgaleal space and the periosteum of the skull or pericranium.

The skin of the scalp is the thickest in the body. It is maximal over the occipital and thins progressively to the frontal and temporal areas. The skin is attached to the galea or fibroaponeurosis with connective tissue. Between the layers run the blood vessels, lymphatics and nerves. The aponeurosis rises from the muscle groups - frontalis, auricula and occipitalis, and it continues into the fascia of the face. It is firmly held at the points of origin. The major arteries of the scalp frontal, supraorbital, superficial temporal, posterio-auricular and occipital supply the anatomically related areas, and traverse the superficial surface of the galea to supply the skin and subcutaneous tissues. The inner surface of the galea is by comparison avascular. Bridging vessels run from the galea to the periosteum where the bone provides a rich blood supply. The venous network runs over the galea. In addition venous channels pass between the periosteum and the aponeurosis.

The anatomical features as described apply to both the adult and child's head, but in infancy the protective hair cover is less than in the older child and adult.

The generous blood supply to the scalp tissues ensures that wounds tend to heal satisfactorily. The arterial vessels are a potential source of haemorrhage. It is however usually only in the infant, and in the atherosclerotic adult, that blood loss may be profuse and lead to anaemia and hypovolaemia. It is however an assumption that should not be made until other causes have been excluded.

The site at which scalp injury is seen is relevant, not only to the anatomical features of the skull coverings, but also to the structures within the scalp, which may be at risk from focal trauma.

Scalp injury may not be a feature of diffuse brain injury, which follows high velocity whiplash forces or impacts on soft surfaces.

Injury following impact may manifest as a single wound or a combination of features, and at more than one site. The mobility of the scalp may result in a scalp wound being located other than immediately over a fracture. Scalp injury may be seen in the form of

1. Lacerations
2. Bruising, swelling or scalp haematoma
3. Abrasions/contusion
4. Incised wounds
5. Penetrating wounds which may conceal a foreign body and
6. Defects of the scalp due to avulsion or tearing injuries

Laceration

Lacerations occur as a result of blunt trauma applied over bony skeleton. They may be superficial involving only skin, or may penetrate subcutaneous tissue and the scalp aponeurosis exposing the subgaleal space and the surface of the periosteum. They may be simple, multiple or stellate. The wound edges may be contused and irregular. Force sufficient to split the galea may be sufficient to fracture the skull.

Bruising, Swelling or Scalp and Haematoma

Bruising and swelling of the scalp with or without surface skin abrasion, results from contusion of the skin or bleeding as a consequence of local trauma.

Subgaleal bleeding can produce haemorrhage, and secondary serous effusions, delineated by the attachments of the galea itself.

Abrasions

Abrasions of the skin resulting usually from friction injury may occur in isolation, but in childhood often overlie an area of swelling or contusion. The breach in the skin may predispose to infection.

Incised Wounds

These are a feature of injury with sharp implements, either accidental or more commonly as a consequence of assault.

Penetrating Wounds of the Scalp

These are seen as a result of high velocity missiles, or penetration with sharp objects. A minority of wounds due to penetration by narrow implements may go unsuspected if the history of events is not available and an entry wound is not recognised as such. Disruption of the scalp and underlying structures are a consequence usually of firearm misuse or explosive incidents.

Defects of the Scalp

These are generally the result of avulsion forces applied to the scalp/hair.

Cephal haematoma

Subperiosteal haemorrhage occurs most commonly as a birth injury and is usually located over the parietal region. It resolves spontaneously in the majority of cases. Some may calcify leading to skull deformity.

Epicranial Hygroma

This is seen in the young child usually below the age of four years, where it often overlies a linear fracture detectable on x-ray. There is often a delay between the injury and the manifestation or detection of the swelling and the fracture. Spontaneous resolution after days or weeks is usual. Aspiration to speed up the processes is to be avoided, because of the risks of infection.

A skull fracture in childhood may cross the suture lines, leading to the risk of growing fracture and leptomeningeal cysts. When noted bilaterally, abuse of the infant should be excluded.

The Management of Scalp Wounds

In this Study the Casualty Medical Officers saw 2,466 scalp lacerations and 961 abrasions. Attending children's scalp wounds is a frequent task requiring surgical toilet, control of bleeding and suturing, or using an alternative method of closure. Many children are brought to Accident & Emergency Departments primarily for this service. There is however an appreciation amongst parents and carers, that the head trauma which resulted in the visible evidence a scalp wound, might be associated with more serious complications.

The medical officer will obtain the history of the event, and examine the child neurologically. The compatibility of the features of the scalp wound with the cause and mechanism of injury should be confirmed. The doctor may consider at this point whether a skull xray is warranted.

The care of the wound after infiltration with local anaesthetic and shaving of the hair around the edges, includes a thorough surgical toilet and debridement. Exploration for a foreign body may reveal glass or vegetative material, which can be removed. Further exploration through the larger deep wounds with a gloved finger may disclose a skull fracture which may be depressed. There is a much greater likelihood of visualising or palpating a fracture if the galea is breached.

Exceptionally, in severe trauma, the fracture may be obvious, comminuted and with the intracranial contents visible or extruding through the wound. Cerebrospinal fluid may also be evident.

There are significant problems in detecting a fracture through a small laceration in an uncooperative, frightened child.

Xrays are therefore essential if the doctor believes there may be a fracture present. Special tangential views are indicated if depression is suspected.

If a fracture is excluded the doctor will proceed to close the wound, in two layers if the galea is breached. Recently acquired simple lacerations, subjected to a thorough surgical toilet will not normally require antibiotic prophylaxis. The generous blood supply of the scalp and a sound technique will usually result in healing within a week, in the majority of cases.

Wounds inflicted in high risk circumstances, a playing field, or with a dirty implement as in assaults, or where there is a possibility of serious contamination may require prophylaxis with broad spectrum antibiotics. The risk is greater if the wound edges are contused or there has been any delay in presentation.

The Author has experience of two children with head wounds who developed gas gangrene of the scalp, due to injury, whilst in swimming, in water heavily contaminated by cattle. Infection of facial or forehead and periorbital wounds with organisms from the upper respiratory tract occurs occasionally in children. Necrotising fascitis of the head and face has been seen recently, and reported increasingly.

Tetanus prophylaxis is essential. Cephalic tetanus carries a very high mortality. It cannot be assumed that full immunising courses of tetanus toxoid have been given and a protective status maintained. A minority of infants are not immunised for a variety of reasons. Where necessary antibody status can be checked, but rarely is. The administration of tetanus immunoglobulin of human origin provides immediate protection, but for a short period only, 3-4 weeks. The first dose of a course of tetanus toxoid should be administered in a site on the opposite side of the body at the same visit.

The wound, which is complicated by evidence of a fracture, presents more of a problem. Over linear fractures the wound may be closed, antibiotics administered and the patient admitted for observation.

Compound depressed fractures need to be discussed with a Neurosurgeon, particularly if there is comminution and the dura is breached. Prophylactic antibiotics should be administered immediately with a broad spectrum prior to transfer. Wounds associated with defects should be covered with a sterile dressing, moist with normal saline. After resuscitation is complete and the patient is stable, transfer to neurosurgery should be arranged.

The contusion, which has significant deep abrasion, should be treated in the same way as a laceration, particularly if a fracture is associated. Dressings are difficult to keep in place on the head. The majority of wounds can be left exposed, providing instructions are given not to interfere with the suture line. Local antibiotics applied to the suture wound twice or thrice daily is a treatment borrowed from plastic surgical practice. As few wounds, which are uncomplicated, become infected, its value has not been tested in Accident & Emergency Departments.

When the frequency of fracture is related to the cause of injury it is seen that falls, the largest numerical group, has the lowest fracture rate, in the Emergency Department.

Road Traffic Accidents, particularly those involving child pedestrians and cyclists has the greatest incidence of fracture.

The identification of road traffic accidents as a cause of more severe head and cerebral trauma in childhood is likely to prompt Casualty Medical Officers to request skull xrays, in this group of patients.

The low incidence of fracture in the larger number of children, who fall may provide an opportunity to reduce the number of requests for xrays. The cause will not be the only factor influencing the doctor.

The scalp injury feature, the site of the impact and the mechanism may need to be taken into account as may symptoms and neurological signs.

It has been suggested that the nature of the scalp injury resulting from a particular cause might influence the casualty medical officers decision to request skull xrays. The cause of injury, be it a fall or a category of road traffic accident might result in a scalp injury with a higher or lower risk of skull fracture. The cause of the injury, was examined in relation to the nature of the scalp wound sustained and the age and incidence of skull fracture. The results are shown in TABLE 4(xiv) – (xviii).

When the causes of injury were examined in all age groups, the absence of any recorded scalp feature was noted in 868 children, only seven of whom sustained a skull fracture, 0.8%. The presence of swelling of the scalp was noted in 1,685 and 57 fractures were detected. The incidence was highest in children hurt in road traffic accidents, followed in frequency by falls in sport/play and at home. The vulnerability of the infants skull is again demonstrated where 14/17 fractures resulted from falls 3.4%.

Abrasions and contusion of the scalp was recorded in 961, 22 with fractures, 2.3%.

The incidence was highest in the road traffic accidents followed by falls.

The short superficial lacerations, a large group, 2,342 revealed only nine fractures, 0.4%. It was not recorded in road traffic accident trauma. The highest incidence of fractures was recorded in child abuse.

The long superficial lacerations of which there were 40 had no fractures detected from all causes.

The deep short lacerations of which there were 62 had three fractures, two due to assault and one, a fall at play/sport, 4.8%.

The deep long lacerations 15, revealed four fractures, 21% resulting from falls and a pedestrian road traffic accident.

Superficial lacerations are confirmed as being associated with skull fracture, whatever the cause of injury in only 0.4% of cases. It forms a large group, in the majority of which requests for skull xrays could be reduced, whatever the cause with very low risk of missing a fracture. The suspicion of a foreign body may justify examination however.

The presence of galeal laceration is indicative of more significant trauma, with fracture present in 4.6%, and 21.1% of cases. The clinical features justify the skull xrays, whatever the causes identified. Assault, with its focal impact, may result in a depressed fracture. Skull xray best demonstrates this type of fracture though specialised views may be required.

It must be remembered when there is a breach in the scalp, a foreign body may be present. Skull xrays are the most reliable means of detecting opaque foreign material.

Large superficial wounds might be amenable to exploration, but in the young child, under local anaesthesia, the procedure may be difficult. Xray by locating the foreign body can also facilitate and confirm its removal.

4.(a).2. Summary of Results

A scalp injury provides confirmation of trauma to the head. The majority of wounds in childhood may be no more than minor cuts and may not be associated with skull or intracranial injury. This Study classified wounds, and related them to more serious injury. The nature of the wound and its effect on management decisions by the Casualty Office were examined.

	N	%
No external injury was recorded	868	15
Swelling only	1683	28
Abrasions/Contusions	961	16
Superficial Laceration < 5 cms	2342	39
Superficial Laceration > 5 cms	40	0.7
Galeal Laceration < 5 cms	65	1.1
Galeal Laceration > 5 cms	19	0.3

The scalp injury may reflect the activity of the child and therefore the scalp features were related to age, Table 4(a)(ii).

Scalp swelling and abrasion/contusion were most common in infants whilst lacerations were uncommon.

Galeal locations were most common over five years of age, and were not seen at all in infants.

Long superficial lacerations were the least frequently observed scalp injury, and may have been incised wounds, but may mask penetration of the skull or foreign body.

The particular features of scalp injury, might have influenced the doctors decision to request skull xrays.

The doctors decision to request skull xrays and the fractures identified are shown Table 4(a)(iii).

When related to age there are differences in the age groups Table 4(a)(v).

Fractures Under one Year

When the features of scalp injury under one year are examined in infants, it was noted that 17 fractures, 9.3% occurred in the presence of swelling or with abrasions/contusions. In this age group no fracture was detected where scalp trauma was not recorded.

Lacerations as one might expect were infrequent at this age, and there were no fractures associated.

The total absence of a scalp feature with a fracture may indicate delay in presentation or child abuse.

Preschool Group

In preschool children swelling was associated with 14 fractures; 1.9%, abrasions and contusion; five fractures 1.2%. Five fractures were found in the absence of scalp injury 1.5%.

Lacerations formed the largest group of scalp injuries, 1,108, but the fracture incidence was only 0.3%, and was present in the short superficial lacerations.

No fractures were detected in 23 preschool children who had galeal lacerations.

School age group 5-11 years

35 fractures occurred in this group of children. The largest number occurred in association with swelling – 19 fractures, but the highest incidence was in children with lacerations through the galea. TABLE 4(a)(v).

Older Children 12-14 years

Swelling was associated with five fractures, 3.7% and short superficial lacerations were associated with three fractures – 1.7%.

The infrequent long superficial lacerations revealed no fracture. One possible explanation may be that these were incised wounds.

All Ages

Deep lacerations 77, penetrating the galea, were not seen in infants. The numbers increase with age. The incidence of skull fracture showed a dramatic rise 5.3% and 16.7% in 5 – 11 year olds, 12.5% and 66% in 12 – 14 year olds. 4.6% were associated with short galeal lacerations and 21% with galeal lacerations > 5 cm..

Scalp Injury – Univarate Analysis

The nature of scalp injury in children under one year was significantly different to that in older children (chi-squared=204.7, df=6, p<0.0005). As can be seen from the figures, most infants presented either with swelling 38% or no external injury (28%) whereas older children presented more often with a superficial laceration less than 5 cms long (42%) with 27% presenting with swelling only.

The probability of a child presenting with a head injury resulting in a skull fracture was found to be dependent on the nature of the scalp injury (=106.7, d.f.=6,p<0.0005). In particular children with a superficial laceration (of any size) had a substantially lower number of fractures than expected.

When all children with a superficial laceration (regardless of length) are compared directly to other subjects they demonstrate a significantly lower risk of skull fracture (chi squared = 47.8,d.f.=1, p<0.0005) and have an odds ratio of 0.13 (C.I.=0.07,0.26). Therefore a child with a superficial laceration is a fifth as likely to result in a skull fracture, as children with other scalp injuries.

When all children with a laceration through the galea, (regardless of length) are considered as a group, and compared directly to other subjects, they demonstrate a significantly higher risk of skull fracture (chi squared=19.5, d.f.=1, p<0.0005) and had an odds ratio of 5.0 (C.I. = 2.3, 11.2). Therefore a child with a laceration through the galea is more than five times more likely to result in a skull fracture than children with other scalp features.

The odds ratios and 95% confidence intervals for each nature of injury are:

	Odds Ratio	CI
No external injury	0.45	(0.22, 0.93)
Swelling only	3.21	(2.20, 4.68)
Abrasions/contusions only	1.62	(1.04, 2.52)
Superficial lacerations < 5 cms long	0.13	(0.07, 0.26)
Superficial lacerations > 5 cm long	0.98	(0.98, 0.99)
Lacerations through galea < 5 cm long	2.59	(0.80, 8.38)
Lacerations through galea > 5 cm long	14.52	(4.74, 44.47)

The results of the expected and observed number of fractures by nature of the injury is shown in (Appendix J).

The sex of patients presenting with a head injury was found to be dependent on the nature of the scalp injury (chi squared=74.02, d.f.=6, p<0.0005).

In particular females were more likely to present with a superficial laceration (chi squared = 54.07, d.f.=1, p<0.0005).

The number of patients of each sex examined under a hypothesis of independence is show (Appendix J).

4.(a).3. Conclusions

Skull Fracture/Scalp Injury

1. Skull fracture was confirmed as being dependent on the nature of the scalp injury

1. The nature of the scalp injury varies with age, infants being very different from older children..

3. The sex of the patient was found to be dependent on the nature of the scalp injury. In particular females were more likely to present with a superficial laceration.

4. The infants most commonly present with scalp haematoma/abrasion, contusion, in which there were 23 fractures. Superficial lacerations did not produce skull fractures at this age.

5. Children with galeal lacerations, a small group, had five (5) times the risk of having sustained a fracture, with the highest odds ratio being lacerations greater than 5 cms in length, almost fifteen (15) times the risk of skull fracture.

6. Children with a superficial laceration are one fifth as likely to have a skull fracture as those with other scalp features.

7. In reaching guidelines for requesting skull xrays to detect a fracture it would be reasonable to withhold skull xrays in superficial lacerations, providing no other factors operated, particularly if the site also had a low risk, e.g. frontal.

8. In children with lacerations through the galea, skull xrays are indicated – including views for depressed fracture because of the high risk, unless the criteria for immediate CT Scanning are met.

9. Infants have a high risk of skull fracture, seen most commonly with scalp haematoma/contusion. There should be a liberal policy with regard to skull xrays in this group.

10. The value of skull xrays where scalp wounds are associated with a depressed fracture is not controversial.

11. They are also of value in detecting opaque foreign bodies in open wounds and may detect penetrating injury.

The identification of the characteristic scalp wounds can influence management decisions.

4.(b) Site of Injury to the Head

4.(b).1. Introduction

The site at which injury is inflicted upon the head, is commonly identified by a visible or palpable scalp injury, though there are exceptions. The value of knowing the site of focal impact relates to the potential for identifying an underlying fracture and the intracranial structures which might be at risk. The potential for complication - haemorrhage, arterial and venous, may result from direct injury to a vascular channel. A fracture may involve an air sinus with the risk of intracranial infection. Wounds associated with underlying fractures, particularly those penetrating the scalp aponeurosis, or with depression of the skull cause a serious risk of infection. Some sites are more fragile or vulnerable to forces applied and this varies with age. The particular risk of extradural haemorrhage following injury at the temperoparietal site warrants particular and urgent action. The absence of a detectable site of injury, may be explained by the rapidity with which the child is presented for medical care. It may also be absent, with evidence of severe cerebral dysfunction, when acceleration/deceleration forces have been applied, resulting in diffuse axonal injury. Similarly, absence of a detectable site or scalp injury may be associated with shaking or with forcible impacts on soft surfaces, particularly in infancy when suspicion should prompt investigation for possible abuse, particularly when there is delay in attendance. The site at which head injury may be inflicted on the scalp may be relevant to any intracranial complication, which follows. The local scalp injury may be associated with a risk of infection and of underlying fracture.

4.(b).2. Summary of Results

The site of injury most commonly identified was frontal, 3082 children and 51%.

The parietal site was identified in 700 and 12% and the temporal least often, 280 children and 5%. The poor clinical definition of the boundaries and the relationships to the middle meningeal vasculature can justify the combination of these numbers.

The occipital site was affected in 1019 children or 17%. (There is no protective reflex activated for this location of injury). Velocity of impact may be greater.

In 13% no site of injury was identified, there being no visible or palpable scalp lesion. Knowledge of the site of trauma is relevant to the risk of injury to the underlying structures vascular channels, venous and arterial, and vulnerable structures within the brain.

When the site is identified along with other clinical features, attention may be drawn to the risk of the particular complications of extradural haematoma, i.e. temporoparietal, where a boggy scalp haematoma may be detected by palpation.

Age affects the site of injury, and may reflect the mobility and relative instability of the toddler. The maturity of the skull needs also to be taken into account.

When the site of injury was matched to the doctor's request for skull xrays, the largest percentage of requests related to the frontal site.

When the site and the fracture detected are matched, the frontal site had the lowest incidence of fracture.

Whilst 39 fractures were detected at the parieto-temporal site, this high incidence of fracture is confirmed across all age groups, but is highest in infants, where 35% of the fractures were detected.

The 12-14 year olds were also vulnerable to fractures at the temporoparietal sites, though they were numerically under represented as a group.

Risk of Fracture/Site of Injury - Univarate Analysis

The probability of a child presenting with a head injury resulting in a skull fracture was found to be dependent on the site of injury. (chi-square = 103.4, df = 5, $p<0.0005$).

In particular children with an injury at the parietal area have substantially more fractures than would be expected.

The number of skull fractures by the site of injury and the expected number under a hypothesis of independence shows substantially less at the frontal site and lower than expected at the occipital site. Injury at more than one site had higher than expected number of fractures. (Appendix J).

Sex by Site of Injury

The sex of patients presenting with a head injury was found to be dependent on the site of injury to the skull (chi squared=25.15, d.f.=5,p<0.0005). In particular females were less likely to present with an injury to the temporal or parietal areas, (chi squared=14.16, d.f.=1,p<0.0005) and more likely than males to present with no detectable site of injury (chi squared=13.56, d.f.=1,p<0.0005).

Temporo-parietal Injury

When children with an injury to the tempero-parietal areas are considered as a group and compared directly to other subjects, they demonstrate a significantly higher risk of skull fracture (chi square = 31.6, df =1, p<0.0005) and have an odds ratio of 2.9 (CI = 2.0, 4.4). Therefore a child presenting with an injury to the tempero-parietal site is about three (3) times as likely to result in a skull fracture, than children with injury at another site.

The odds ratio and 95% confidence intervals for each site are:

	Odds Ratio	**CI**
None	0.25	(0.09, 0.69)
Frontal	0.27	(1.17, 0.42)
Temporal	1.16	(0.51, 2.67)
Parietal	3.44	(2.28, 5.19)
Occipital	1.83	(1.20, 2.80)
More than one site	5.63	(3.02, 10.53)

4.(b).3. <u>Conclusions</u>

1. More than 50% of the children presented with injury to the frontal site.

2. The frontal site produced the lowest yield of fractures.

3. Children presenting with a frontal injury had the lowest risk of fracture – odds ratio only 0.25 (CI 0.09,0.69).

4. Despite this the group resulted in requests for skull xrays in 58%. Knowledge of this low risk might substantially reduce unnecessary radiography without endangering the patient.

5. When the frontal site and superficial lacerations are matched, the scalp injury is also shown to be associated with a very poor yield of fractures on skull radiography.

6. The vulnerability of the temperoparietal site to fracture, and the potential injury to underlying vascular structures justifies a liberal use of skull xrays, unless the criteria for immediate CT Scanning are met.

7. The parietal site is affected commonly in infants, who should qualify for a liberal use of skull xrays.

8. Occipital fractures may be associated with less common clinical signs and symptoms. Posterior fossa haematoma may be detected by CT scanning, when the doctor is alerted by an occipital fracture. Delay may lead to sudden and unexpected complications.

9. Occipital fracture may be associated with contra-coup injuries of the frontal lobes again, presenting difficulties for the doctor in the assessment of the young patient.

5. HEADACHE AND VOMITING

5.1 Introduction

Headache is a symptom associated with a variety of conditions affecting the intracranial contents, of which trauma is but one. It may be caused by a number of pathological processes and mechanical factors, and may also complicate injury at other body sites. It may coincide with head injury but have other causes in the multiply traumatised patient. Pain may also be experienced at the site of an injury to the head., and may be difficult, in children to separate from true headache, with which it may however coincide.

Headache is a subjective symptom, difficult to confirm in the younger child. It may, as a result, be under-recorded. Distress and irritability may raise suspicion of its presence.

Vomiting, by contrast, is objective and rarely other than genuine in childhood and readily confirmed.

Headache and vomiting either alone, or combined, complicate head trauma and cerebral dysfunction. Vomiting is generally considered to be more common in children with head injury, than adults with comparable trauma, and in the former may occur in the absence or without confirmation of headache.

The Study aimed to discover the frequency with which headache and/or vomiting occurred immediately following head injury, and to identify factors, or clinical presentations with which the symptoms were associated.

The symptoms were also examined to identify the relationship to the investigations requested, in particular skull x-rays, and the results of that examination.

The persistence of headache and/or vomiting was believed to influence medical officers in their decisions to admit children for observation, whatever the result of the skull x-rays.

Headache may be under-recorded in infants, who are unable to communicate this symptom.

Following head injury pain may be experienced, which the young child is unable to communicate, and an older child to differentiate from pain arising at the site of the impact, from true headache, or the two may co-exist. Headache may occur in isolation from vomiting or the two may be combined. The precise mechanism of the headache

may be difficult to identify. Following concussion headache is common and of a variable degree of severity. In moderate or severe injury subarrachnoid haemorrhage may be the source, usually of quite severe headache with associated symptoms of meningeal irritation. In the Accident & Emergency Department soon after the traumatic event, raised intracranial pressure is unlikely as an explanation. The exception would be the child presenting after a period of delay, and in some cases of child abuse, or in those who return following the development of a complication.
Vomiting is objective, its cause and origin variable, and related to the nature of the head injury. Specific neurological patterns may be manifest.

The majority of children in the Accident & Emergency Department have sustained minor head trauma. As the data shows only a minority vomit, and even fewer vomit more than once. However vomiting is a symptom raising suspicion of potential complication, and is a factor in decisions to admit the patient for observation. It is of some interest, that confining the child to bed, even briefly, often results in a cessation of vomiting. It is also noted that children who return from home with vomiting, after initial discharge, often settle rapidly with bed rest in hospital. In the absence of specific treatment the majority of children recover within a few hours.

5.2 Summary of Results

5993 children presented in the Accident & Emergency Departments.

	N	%
Experienced no Headache or Vomiting	4562	76
Complained of Headache	660	8
Vomited once /more than once	484	11
Had both Symptoms	287	5

If these complaints are evidence of cerebral dysfunction, only 24% were affected.

The age of the child may have influenced the absence ofconfirmation of headache in the youngest children.

Vomiting is objective and readily recognised and rarely not organic in origin.

The association with intracranial complications might be expected to prompt the Casualty officer to request xrays. This proved to be the case, though other factors may have influenced that decision.

Headache and vomiting occured most frequently in the older children 5 – 11 years and 12 –14 years – Table 5(ii).

The Casualty Officer used discretion in selecting patients, though 58% without these symptoms were xrayed, perhaps for other reasons? 92% with both headache and vomiting were xrayed.

The request increased to 92% when both symptoms were present – Table 5(iii).

It might be expected that in the presence of either or both symptoms the Casualty Medical Officer would request skull xrays.

Children with neither symptoms, 2665.	58%
Headache	76%
Vomiting	82%
Headache and Vomiting	92%

When the symptoms are matched to the identification of skull fracture:

No Headache or Vomiting	1.2%
Headache Only	2.1%
Vomiting Only	2.7%
Headache and Vomiting	7.0%
All Vomiting	4.3%
All headache	3.6%

The results related to the different age groups are shown in Appendix 5, Table 5(v).

When the symptoms of headache/vomiting are matched to the mechanism of injury, blunt head impact dominates, with road traffic accident's being the commonest cause, perhaps reflecting velocity.

When compared with adults, children vomit more commonly after head injury, Table 5(vii).

Statistical Analysis – Univarate Analysis

1. Risk of Fracture by Headache

The probability of a child presenting with a head injury resulting in a skull fracture was found to be dependent on a history of headache, (chi squared=41.1, d.f.=1, $p<0.0005$). The number of skull fractures having the presence of headache, under a hypothesis of independence (under HO : skull fracture is independent of headache, (Appendix J).

Headache had an odds ratio of 3.9 (CI 2.5, 6.0).

Therefore a child presenting with a history of headache is almost four (4) times as likely to have a skull fracture than a child without any history of headache.

The odds ratios and 95% confidence intervals are:

	Odds Ratio	**C.I.**
No Headache	0.26	(0.17, 0.40)
Headache	3.90	(2.5, 6.0)

2. Risk of Fracture by Vomiting

The probability of a child presenting with a head injury resulting in a skull fracture, was found to be dependent on a history of vomiting, (chi squared = 35.2, d.f.=2, p<000.05). The number of skull fractures confirmed with vomiting and the expected number seen under a hypothesis of independence is shown in (Appendix J).

When all children with a history of vomiting (once or more than once), were considered as group, and compared to children with no history of vomiting, they showed an odds ratio of 3.2 (CI = (2.1, 4.8). Therefore a child presenting with a history of vomiting is about three times as likely to have a skull fracture than children without a history of vomiting.

3. Risk of Fracture by Headache and Vomiting

The probability of a child presenting with ahead injury resulting in a skull fracture was found to be dependent on a history of headache associated with vomiting, (chi squared=48.2, d.f.=1, p<0.0005). Headache and vomiting had an odds ratio of 5.01 (C.I.=(3.0,8.3).

Therefore a child presenting with a history of headache and vomiting was five (5) times as likely to have a skull fracture, as those who do not have headache and vomiting:

	Odds Ratio	**CI**
No headache, no vomiting	0.20	(0.12,0.33)
Headache and vomiting	5.01	(3.0, 8.3)

4. Sex, Headache Vomiting

The sex of patients presenting with a head injury was found to be independent of a history of headache.

The number of patients of each sex by a history of headache and the expected numbers under a hypothesis of independence is shown (Appendix J).

5. Sex and Vomiting

The sex of patients presenting with a head injury was found to be dependent on a history of vomiting (chi squared=9.93, d.f.=2, p=0.007).

The expected and observed numbers of patients of each sex by vomiting under a hypothesis of independence is shown, (Appendix J).

6. Headache, Vomiting and Unconsciousness and Skull Fracture

If we consider children presenting with a history of unconsciousness (of any length) with headache, and vomiting once or more than once, and compare this group to all other patients, we find that this group has a significantly greater risk of skull fracture than other patients (chi squared = 53.8, d.f.=1, p<0.0005). Although this represents a very small proportion of the children seen (63, 1.1%), there is a very high odds ratio (9.5, CI= (4.6, 19.7). Within this Study patients presenting with headache, vomiting and any loss of consciousness, were more than nine (9) times as likely to have a skull fracture than other patients.

For detailed statistical analysis see (Appendix J).

5.3 Conclusions

1. Headache increases the risk of skull fracture by four (4) times.

2. Vomiting increases the risk of skull fracture by three (3) times.

3. Headache and vomiting combined increases the risk of skull fracture by five (5) times.

4. The sex of patients with head injury was found to be independent of a history of headache.

5. The sex of patients with head injury was found to be dependent on a history of vomiting.

6. Headache and vomiting with head injury and any history of unconsciousness increased the risk of skull fracture nine (9) times, compared with children without these features.

6. DIAGNOSTIC IMAGING IN THE ACCIDENT & EMERGENCY DEPARTMENT

6.1 Introduction

The patient who has sustained trauma to the head has in the past had the results of the injury assessed, following clinical examination, by skull xrays. At the time this data was collected it was the only radiological investigation immediately available to the emergency doctor. CT brain scanning has become more widely available, though it is not always accessible over the 24 hours, other than for selected patients.

Skull xray series involve three or four views, an anteroposterior, Townes and one or both lateral projections. Specialised views can be requested, such as tangential views to confirm depressed skull fractures, or brow-up views, to detect intracranial air. Confirmation of basal fractures can be obtained by tomography, but this is not normally requested, and the diagnosis is made on clinical criteria. If specialised views of the base are required they can be obtained by using special techniques in the CT scanner.

In the Emergency Department the doctor, having obtained the history of the accident and carried out a clinical examination, will decide on the investigations required. Despite opinions expressed regarding the limited value of the examination and its results, skull xray is still the most common investigation requested following head trauma. It is likely to remain so until such times as CT scanning of the brain, with its acknowledged superiority, in demonstrating and defining cerebral injury, is immediately available, 24 hours a day, in hospitals receiving head injured patients.

Computerised axial scanning of the brain is the investigation of choice for the child who has sustained cerebral injury. In those who present in the moderate or severe category it should be the first diagnostic procedure. The situation with regard to minor head injury remains both controversial and affected by the availability of resources.

A review of the controversy relating to skull xrays is presented, because some of the arguments presented by Radiologists for reducing skull xray usage, may be applied to CT scanning for some, but not all of the reasons given for limiting skull films.

The frequency of skull fracture varies in relation to the population studied, being highest in those who die of their injuries on site or shortly afterwards, and in neurosurgical units and lowest in emergency departments. Between these two groups will be a variable incidence of fractures in those admitted to hospital, and the reasons for that admission.

Patients who are unconscious on arrival in the Accident & Emergency Department with evidence of moderate or severe injuries, will almost always be subject to skull xrays as part of their initial assessment and resuscitation except in those emergency units which have access to CT scanning over the 24 hours.

The larger group of mildly head injured patients will continue to be assessed, without CT scanning, at least in the foreseeable future, in the United Kingdom. The role of skull xrays has been a source of controversy. Radiologists were concerned with the resource implications of an expensive service. In children there was the additional risk of repeated exposure to radiation over the years. In the climate of financial audit in the United Kingdom clearly unnecessary and unhelpful investigations cannot be justified However the formulation of any protocols must ensure that the quality of total care afforded to the patient is paramount. It is accepted that withholding a procedure does not necessarily imply unacceptable practice. It does however require sound clinical judgement and experience, components, which are not always an integral part of 24 hour Accident and Emergency services in the United Kingdom. The staffing of such departments by relatively junior doctors, inexperienced in the management of trauma and head injury in particular, and the demands made, frequently out of hours, by the head injured patient are factors which have to be taken into account. So does the reason why junior doctors request more investigations, than might be required by more senior doctors, a feature which those remote from clinical responsibility or direct patient contact choose to criticise. It is essential to identify the value of an investigation to the Accident & Emergency doctor, as perceived by that doctor. If his understanding of the value of the xray is flawed, it is the responsibility of all those involved in emergency care to remedy that situation. There is also a need to appreciate that a negative skull xray is used more frequently than a positive interpretation in the decision making process. Of equal importance is the doctors ability to interpret the xrays correctly.

At the present time, some agreement has been reached between radiologists and clinicians on the discretionary use of skull xrays, without loss of quality of patient care or risk for the patient or physician. It is the level of reduction and the identification of patients at particular risk, that has not been fully resolved. Emergency doctors reflect this in the continuing request for skull xrays.

The foundation of recommendations and guidelines must be based on clinical criteria, and an appreciation of why doctors continue to request skull xrays?

It is also essential that services benefiting from reduced demands do not transfer the burden to another area of health care. More patients may be admitted for observation, there may be an increase in litigation, and a less favourable outcome for the patient, with all that implies for the physician and health care services.

At the present time, one would be ill advised to ignore the views which suggest that trauma cases are badly managed in the UK and that head injuries form a substantial part of the trauma group(The Management of Patients with Major Injuries 1988). Expertise and resources need to be available at the optimum times, to doctors trained and supported, not only in their individual departments, but by the wider professional body of experts. In this way standards of good clinical practice can be agreed, and alleged fears of a medicolegal nature may be virtually eliminated from consideration. Research and audit will enable more rational policies to be formulated. No guidelines will ever provide total elimination of error, but casualty doctors in the front line of medical care will be able to function with some security in the application of multidisciplinary management protocols.

It should not be forgotten that there are complex factors in the emergency doctors decision making processes, and as the controversy of the past three decades has shown, always an expert willing to present a differing view or interpretation, in the event of error.

6.2 Summary of Results

1. There was a 64% request rate for skull radiography, clearly indicating that overall the requests were not made routinely, as claimed by many authors in the literature.

2. The largest numbers of children were seen by Senior House Officers and this grade of doctors had the highest rate of requests for skull xrays. There was however wide variation within the grade from as low as 30% to 100%. This may reflect inexperience or lack of knowledge of Guidelines for skull xrays.

3. It was of interest that Senior House Officer's in the Royal Aberdeen Hospital requested substantially fewer xrays, 45%, compared with 68% at Monklands mixed Accident & Emergency Unit.

4. There was a poor yield of fractures, 2.6% overall, from skull radiography.

5. 102 skull vault fractures and, nine base of skull fractures were diagnosed clinically, and one confirmed radiologically.

6. Casualty Officers made significant errors of interpretation. There were both false positive 45, and false negative 15 fractures diagnosed. The former led to admission, and the latter represented a 15% failure for the positive films at possible risk to the child.

7. Skull fractures were related to age with 7.7% occurring in infants, and in both males and females. The lowest incidence was in the preschool age group. Older males had almost double the rate of females of the same age, 12-14 years.

8. When the clinical features were examined in relation to xray requests, certain clinical features influenced requests. Details are shown in each Section.

9. Variations in requests and yields of fracture in more senior doctors compared with Senior House Officers, may have reflected experience, application of Guidelines or that they were involved with the more seriously injured.

10. This Study has identified features which carry a risk of skull fracture, which might both reduce the number of requests and increase the yield of fractures.

11. The realisation that in a six month appointment a Senior House Office might see two or three skull fractures, indicates a need for teaching and supervision.

12. False positive and false negative interpretation similarly showed the need for tuition in xray requests and interpretation.

13. A further survey of xray usage in Monklands Hospital after dissemination of Guidelines showed an increase in xray requests from average 68% to 85%.

14. The reason why doctors request skull xrays is examined under Guidelines, (Section 14).

15. Multiple logistic regression allows the generation of a model to be applied to the injured patient, incorporating various clinical features, to determine the likelihood of skull fracture. This model could then predict the probability of a skull fracture in that patient.

Multiple Logistic Regression

Univariate analysis is a useful tool for identifying individual characteristics which influence the likelihood of an individual resulting in a skull fracture. However, in a clinical situation a number of factors have to be considered simultaneously in order to assess patients and decide upon appropriate examinations. Multiple logistic regression was performed in order to assess the relative influence of presenting symptoms in determining the likelihood of skull fracture and to construct a model to predict the probability of skull fracture in individual patients.

Prob (Skull Fracture) = $1/(1+e^{-z})$

Where

-0.0466 (Age)

-0.5454 (No external injury) + 0.5923 (Swelling only) + 0.6089 (Abrasions/contusions only) – 0.6462 (Sup lac <5 cm) – 3.6667 (sup lac > 5 cm) + 1.4632 (lac thro galea < 5 cm) + 2.1939 (lac thro galea > 5 cm)

-0.5994 (No Site) – 0.7682 (Frontal Site) – 0.1478 (Temporal Site) + 0.6115 (Parietal Site) + 0.2522 (Occipital Site) + 0.6517 (more than one site)

-0.0025 (No Unconsciousness) + 0.8437 (Unconscious < 5 mins) + 1.2015 (Unconscious 5 to 30 mins) – 4.438 (Unconscious 30 to 60 mins) + 2.3953 (Unconscious > 1 hour)

-0.3529 (No headache) + 0.3529 (Headache)

-0.4018 (No Vomiting) + 0.4289 (Vomited Once) – 0.0271 (Vomited more than once)

-0.5868 (Fall to or bump against sharp edge) + 0.5868 (Other Mechanism)

This model produces a large proportion of small probabilities of skull fracture with a very small proportion of high probabilities. It is therefore essential that patients resulting in a predicted probability greater than 0.03 should be classified as at a high risk of skull fracture and should receive a skull xray. In our sample this would require 581 of 5201 patients (11.2%) to be xrayed and would identify 55.4% of all skull fractures (41 of 74), (note that numbers are reduced to exclude patients without all relevant data). In addition patients could be classified as at low risk if they have a probability of skull fracture lower than 0.003. In the study sample this group would contain 1449 patients (27.9%), four of whom had a skull fracture.

Applying this to a two year old presenting with a laceration through the galea < 5 cm on the frontal site, a history of unconsciousness between 5 and 30 minutes, headache and vomiting more than once after a fall to a sharp edge, we find

Z = -4.1633 – 0.0466*2 (Age) + 1.4632 (lac thro galea < 5 cm) – 0.7682 (frontal site) + 0.8437 (uncons < 5 mins) + 0.3529 (headache) – 0.0271 (vomited more than once) – 0.5868 (fall to or bump against sharp edge).

= -2.621

The probability of a skull fracture is then estimated to be:

Probability (skull fracture) = $1/(1+e^{1.2351}) = 0.0678$

Based on this estimate, we would assume that a skull fracture is relatively likely and would proceed to xray the patient.

As with all clinical condition, the experience of the doctor and other factors, would allow the doctor discretion on requesting skull xrays, proceeding direct to CT Scanning or deciding against requesting skull xrays.

The Benefits and Implications of Detecting a Skull Fracture

The value of skull xray in identifying a skull fracture in the child following recent head trauma alerts the clinician to the risk of complications.

These include:

1. Intracranial and cerebral injury
2. Intracranial haemorrhage
3. Intracranial infections and the abnormalities listed by Gorman(1984).

CT Scanning is the gold standard for investigations of intracranial cerebral injury and intracranial haematoma.

The emergency clinician is faced with a large number of patients, and has been held responsible for "routine" skull xrays, which offer a poor return in terms of fractures detected. This Study has shown that Casualty Officers vary widely in their requests for skull xrays, but many use discretion.

It is a matter of concern that interpretation of the films resulted in the false positive and false negative interpretations, which influenced management decisions, and may put the patient at risk.

In order to reduce the number of skull xrays unlikely to influence management, criteria has been set to provide guidance for doctors. These are incorporated in local protocols and National Guidelines.

This Study has identified and confirmed clinical features with a statistical risk of producing skull fractures.

This enables children to be identified whose injury causes little or no risk of skull fractures and who do not need radiography.

The criteria for skull xray, if modified, could identify those children who have a significant risk of a fracture, and of reducing the number and costs of unnecessary skull series.

Skull fracture has an increased risk of intracranial injury of non-neurosurgical interest, but which requires further evaluation.

Skull fracture has been calculated in children to have an increased risk of intracranial haematoma.

When associated with impairment of consciousness, or a history of amnesia the criteria for CT Scanning are met.

When there is no history of loss of consciousness or amnesia, Glasgow Coma Score of 14 or 15, and no significant symptoms or signs, the identification of a skull fracture alerts the clinician to the risk of intracranial haematoma, which is 80 times more likely to develop in the presence of a fracture.

There is nevertheless disagreement as to whether children with linear skull fracture should be subject to CT Scanning, or whether admission for observation is an acceptable alternative.

Admission to ward areas had been associated with deterioration and delays to neurosurgery.

CT in the youngest children who are alert presents practical and technical problems, in obtaining quality scans.

CT Scanning may require sedation/anaesthesia in the youngest children without indication for CT Scanning other than fracture. This may result in admission to recover from the effects. This remains a dilemma for clinicians in agreeing Guidelines in children.

The number of children requiring admission in this Study based solely on the identification of skull fracture radiologically, was 102 from almost 6000 seen in the

Accident & Emergency Departments. Reducing false positive interpretation of films by training and experience, would reduce unnecessary admissions and CT scans further.

The data did not allow population studies.

The value of skull xray is not in dispute for the detection of depressed fracture, whether compound or not. Its presence influences management decisions.

The infants and children under two years form a unique group. They are more vulnerable than older children to skull fracture and proportionally less vulnerable to intracranial injury and haematoma.

They may however be at risk of abuse in which radiology contributes to confirmation. Skull fracture is occasionally subject to the long term complication of growing fracture.

Significant intracranial injury may occur in the absence of a skull fracture, and its exclusion should not be taken into account in assessing the child with symptoms or signs following head trauma, and CT Scanning should be used, in preference to skull radiography.

7.0 DISCHARGE OR DISPOSAL FROM THE ACCIDENT & EMERGENCY DEPARTMENT

7.1 Introduction

Large numbers of patients attend in Accident & Emergency Departments following head injury. In the majority the injury is regarded as a minor, and discharge home after assessment and investigation is considered appropriate, with instructions to return if progress is not satisfactory. There is a further group whose injury does not appear serious, but who are considered at risk of developing a complication. Following examination and investigation, these patients are admitted for observation. It is essential that in the event of a complication or deterioration, particularly in conscious level, communication with and transfer to the Neurosurgical Unit be expedited.

The majority of children admitted for observation are discharged home within 12-48 hours. A large group of patients with minor head injury and their management by the emergency doctor, has been the source of discussion and controversy.

There is no similar problem with the small proportion of cases, who have sustained moderate or serious cerebral trauma, or whose head injury is accompanied by injury elsewhere, warranting admission. These patients may require active resuscitation, and the Casualty Officer is supported in the management of the child by senior colleagues from the relevant specialties.

7.2 Summary of Results
Discharge/Disposal from the Accident & Emergency Department

When the data is studied there is confirmation that the majority, 88% of children, who sustained head trauma were considered fit for discharge home.

12% were admitted to hospital, of whom 3% had injuries resulting in transfer to Neurosurgery or Intensive Care.

9% warrant observation, further investigation or definitive care. This was provided in a variety of ward situations, under the care of different specialists.

There was variation in the criteria for admission in the different hospitals. In Hull Royal Infirmary at the time of the Study, all children went to a Neurosurgical Ward.

Sex

When the sex of the admitted children was examined, more female children were admitted, but twice as many males went to neurosurgery, reflecting more serious cerebral injury or complication. The largest proportion was in the 12-14 year group.

Causes of Injury

When the causes were examined, road traffic accidents result in admission of 30% of the victims, with 5% being transferred to Neurosurgery. Pedestrians and unrestrained occupants were at greatest risk.

Falls

This large group produced lower rates of admission. 87% - 92% being discharged, depending on the location of their fall.

Assaults/NAI

These patient had a 50% admission rate. There may have been medicolegal, as well as clinical reasons. Suspicion of abuse would require further investigation in a Place of Safety. 5% were transferred to neurosurgery.

Mechanism of Injury

Hard blunt trauma resulted in the highest admission rates 11%, 15% and 24% - 26 children being transferred to Neurosurgery.

Sharp trauma resulted in the lowest admission rates. Penetrating injury was not identified.

History of Loss of Consciousness

92% of children had no history of loss of consciousness and were discharged home.

45% with loss of consciousness of less than five minutes had fully recovered and went home. Admission policies varied. In two hospitals any loss of consciousness resulted in admission.

Details of the wards of admission for varying periods of impaired consciousness is shown in Appendix 7.

Skull Fracture

This was a reason for admission in all the hospitals, if it had occurred within 48 hours. The views of many authors that skull fracture in itself is not indicative of intracranial injury, raises the issue of whether these children, who are asymptomatic require admission or computerised braining scanning.

Children without neurosurgical symptoms or signs might still be a risk of an expanding mass lesion.

This might be excluded by a timely computerised scan in the A&E Department. If normal and stable the child might be safely discharged.

For young children in whom the risk is low, and CT scanning requires sedation or anaesthesia, a period of observation might be considered a reasonable alternative.

7.3 Conclusions

The data confirms that large numbers of children, 5265/5993 – 88% went home. Many sustained minor trauma to the scalp only.

Within the remaining 12% were the minor injuries, where some features caused sufficient concern to result in admission for observation. This is the group of patients, who appearing satisfactory, were considered at risk of developing complications, or had symptoms.

In childhood the vomiting patient requires observation and symptomatic relief. The possibility of childhood concussion is raised. Deterioration not due to a mass lesion may be due to the onset of cerebral swelling, for which to date, there seem to be no reliable predictors. The moderately injured will require admission for definitive treatment for the head and possibly other injuries.

Severe injury, only 3% of the total will require the full resuscitation skills of a multi-disciplinary team, and may subsequently face the hazard of inter hospital transfer. The cause, mechanisms and features of severe injury are shown in the data tables. Appendix 7(a), whilst the care of the moderately or severely injured child is presented in Appendix 7(b).

The decision to transfer a child to a distant Neurosurgical Unit is one of the most difficult a doctor in the A & E Department has to make. It is certainly a situation which puts a heavy responsibility on to the medical officer Unfortunately too often in the past it has been made on the principle of "scoop and run", At the opposite end of the spectrum is delay, which has resulted in avoidable mortality and morbidity reported in past decades, and often in observation wards.

There are inevitably areas in pre-hospital care which have features and requirements in common with interhospital transfer, and with resuscitation within the A & E Department. Having made the decision, action must follow a strict and disciplined pattern. Full resuscitation must have been achieved, based on the principles outlined. There must be adequate assessment of both the neurological condition, and other injuries. A provisional diagnosis should be made, and in the absence of urgency, investigations undertaken. In particular the status of the cervical spine should be established. Skull xrays are normally indicated, unless the criteria for urgent scanning are met. Continuous monitoring ensures that the patient is stable and fully oxygenated. CT of cervical spine will reveal fractures not seen on xray.

Hypovolaemia should be treated by intravenous infusions, and the control of blood loss. Should the latter not have been achieved, consideration should be given to the wisdom of transferring the patient and senior surgical advice is essential. Fractures not requiring immediate treatment should be effectively splinted, and pain relief should be administered. Specialised Transfer Ambulances are ideal with senior experienced medical escorts, and nursing staff.

Monklands Accident & Emergency Department has had for 18 years, a dedicated self sufficient Life Support Trolley designed by the Author. This allows monitoring and treatment during resuscitation and intrahospital activities.

Transfer is effected by placing the Trolley in a dedicated fully equipped Intensive Care Ambulance. Apart from the clear benefits for the patient, there was a dramatic improvement in the knowledge and practice of junior doctors. They had previously been unaware of the principles of care in transit, and the concepts applicable. Unless Trauma Centres are widely established in the U.K., the role of the Emergency Physician in resuscitation and transfer is a challenge, which must be addressed in the interest of head injury survival, and improved outcome, for the foreseeable future, in conjunction with Neurosurgical colleagues.

8. HAEMATOMA

8.1 Introduction

Intracranial haematoma in childhood, as in adults, should be suspected and detected as early as possible. Delay to neurosurgical intervention has serious and often irreversible effects. Doctors in Accident & Emergency Departments have a vital role in the recognition of these lesions and expediting care.

8.2 Summary of Results - Intracranial Haematoma

The Paediatric Study set out to identify the incidence of intracranial haematoma in Accident and Emergency Departments, and factors which might identify risk, before serious intracranial complications occur.

From 5993 children, only 15 intracranial haematomas were identified, an incidence of 1:400 and 0.25%.

Teasdale et al(1990) had identified skull fracture and impaired consciousness as risks for intracranial haematoma in both adults and children, though the calculated risks were less than in adults:

Overall	1: 2,100
With no Skull Fracture/No loss of Consciousness	1:13,000
With a Fracture and Coma	1: 12

Teasdale had not found any subgroups which might identify risk. In this Study I identified features present in the 15 cases.

The primary purpose was to discover if Accident & Emergency Departments were contributing to delays in diagnosis and CT confirmation. The results showed that 13/15 cases arrived in the A&E Department under in two hours, 10 under one hour.

The intracranial haematoma most amenable to surgical intervention and with the least risk of primary cerebral damage is the extradural haematoma, of which there were 3/15.

The causes and mechanisms showed blunt impact trauma and velocity in Road Traffic Accidents were the most common conditions associated with increased risk of skull fractures.

Teasdale(1990) and others have identified loss of consciousness as a risk factor in intracranial injury, including haematoma. Children suffer loss of consciousness less frequently following head injury than adults.

6/15 children with a haematoma gave no history of loss of consciousness, at their examination in the A&E Departments, suggesting that there is need for another risk predictor in children. Skull fracture has been identified as increasing risk in children, though to a lessor degree than adults, Teasdale et al(1990).

Focal neurological signs are indications for CT scanning. In 10/15 there were no focal signs in the A&E Departments and none were seen in the three extradural haematomas . Only one child with a haematoma had a seizure.

Skull fracture and haematoma has been identified as a risk in children, though haematomas are seen in children, without skull fracture.

In the Study there were 15 haematomas associated with nine skull fractures, i.e. 9% of all the vault fractures. One haematoma complicated one of the nine base of skull fractures. Three fractures were linear and associated with the (3) three extradural haematomas.

Haematoma - Univarate Analysis

The probability of a child presenting with a head injury resulting in a haematoma was found to be dependent on the presence of a skull fracture (chi squared=278.34, d.f.=1,p<0.0005).

The identification of a skull fracture increased the risk of an intracranial haematoma by 80 times, odds ratio 86.0 (CI=30.05, 246.10)

However, when children under 1 year old are considered separately they do not show an increased risk of haematoma when there is a confirmed skull fracture, (chi-squared = 0.57, df=1, p=0.811). Children of this age with a skull fracture have an odds ratio of 1.00 (CI=(0.99, 1.00) of having a haematoma.

Where there is a history of loss of consciousness, including the lucid interval, in addition, the odds ratio is 5.2(CI=3.3, 8.0).

8.3 Conclusions

1. Intracranial haematoma in a child in the Accident & Emergency Department is rare 0.25 % - 1:400 in head injured patients.
2. The risk is increased 80 times by a skull fracture, except in infants where the risk is 0.10.
3. The risk is increased five(5) times in the presence of a history of loss of consciousness of any duration, including the lucid interval.
4. In the A&E Study skull fracture secondary to blunt trauma was the feature most commonly identified with an intracranial haematoma.
5. The interval from injury to arrival in hospital, in cases where an intracranial haematoma was subsequently identified showed that the majority presented in less than two hours and before neurological deterioration had occurred.
6. Casualty Officers are unlikely to have first hand experience of a haematoma in a six month appointment. It is essential therefore that guidelines issued to doctors address this problem, so that the haematoma is identified before deterioration is allowed to occur. The numbers are small, but suggest that the identification of a skull fracture leading to CT scanning may be the emergency doctors first indication of risk.
7. The child without skull fracture may well have other features which mandate immediate CT Scanning without requests for skull radiology.
8. Although the risk of haematoma in infants was shown to be statistically low, special note has to be taken of the vulnerability of children under the age of two years to non accidental injury.
9. The detection of a skull fracture in Teasdale's(1990) review showed ensure early CT Scanning. This presents practical problems in the young child if sedation or anaesthesia are necessary to obtain quality scans. The reduced risks in infants is of practical significance, and the alternative of admission for observation may be acceptable, providing the staff caring for such children are fully training and experienced in neurological assessment and that the doctor is alerted by the most subtle changes in the child's cerebral status.

9. EPILEPSY

9.1 Introduction

Seizures or epilepsy in childhood, may precede head trauma and even cause the trauma or be a consequence of the accident and traumatic insult.

Post traumatic seizures are more common in children than adults and occur more frequently in infants and children under the age of five years. The role of abuse in seizure activity requires special consideration.

The seizure which occurs immediately following the blow to the head, often at the occipital site, may be associated with a short period of loss of consciousness, in what subsequently proves to be a minor head injury. This has no unfavourable prognostic significance, and is usually self limiting.

Seizures which occur early or late, and in association with structural cerebral damage have more serious implications.

In the emergency management of the head injured child, two factors are paramount. The control of the seizure activity rapidly and effectively, and an appreciation of the cause and significance in relation to investigations, and treatment of intracranial pathology responsible for their manifestation.

Focal injury, depressed skull fracture and a haematoma can all trigger and sustain seizure activity. Seizures represent in addition a source of secondary insults - with airway obstruction, ventilatory insufficiency, pyrexia and the initiation of a complex cascade of biochemical mediators, both intracranial and systemic, which further compromise the injured brain.

It is therefore essential that the emergency physician is aware of the significance of seizures and competent to make the appropriate decisions, to minimise the effects.

There was little evidence in the literature as to how often the emergency doctor, initially receiving the head injured child might be called upon to deal with such an event.

The post ictal state inevitably reduces the Glasgow Coma Score, and strict observations are required in the presence of head trauma. Where any doubt exists, or where a skull fracture is detected, CT scanning should be requested immediately.

The child in the Accident & Emergency Department, who has a convulsion following head trauma, presents a dual problem for the attending doctor. Management of the comatose patient should be instituted. The airway should be protected and secured, 100% oxygen administered, and the patient protected from further injury. Simultaneously the head trauma should be evaluated.

If a single convulsion resolves without intervention, and is not repeated, no further action may be required, and medication is not indicated. If the fit is repeated, or status epilepticus follows, urgent action is required. A poor response may require muscle relaxants, endotrachael intubation and central control of the epileptogenic foci. The condition presents a severe and life threatening emergency, with the potential for secondary insults to the injured brain from hypoxia and hyperpyrexia, and the systemic effects of excessive muscle activity.

Once stabilised, the child should have an immediate CT scan, and depending on the results, be admitted to a Neurosurgical Unit or ITU. An intracranial mass lesion, or depressed fracture will require surgical intervention, the former immediately.

The child with convulsions requiring neurosurgical transfer should activate the local procedures for safe transfer, escorted by an anaesthetist, paediatrican and nurse. Full resuscitation and control should be established before the journey is attempted.

In children known to be epileptic 6/38 had a fit at or around the time of the injury.

The seven children who had high temperatures, had a convulsion as a consequence of which they sustained a head injury. None had pyrexia from an infective complication of head trauma.

This data demonstrates that post traumatic epilepsy in the first four hours following head trauma is rare, 0.3%.

Head injury complicated by a convulsion adds to the anxieties of the doctor and relatives. Information regarding the prognostic significance is often sought. This is different in children and adults. The twitching and eye rolling observed in children immediately following the impact is rarely a true convulsion. It is usually of no significance, and is not associated with late post traumatic epilepsy.

9.2 Summary of Results

A seizure was recorded in 1% of children associated with head trauma. 18 were post-traumatic and occurred in children with no previous history of seizures. Seven were associated with pyrexia.

38 epileptics sustained head trauma of whom 25 had no related seizure.

The occurrence of a seizure has implications for management decisions including control and imaging procedures.

Detailed results are shown in Appendix 9.

Conclusions

Seizures were rare in the A&E Departments accounting for only 1% of the attenders. Epilepsy complicating head trauma represents an acute crisis for the emergency doctor. Whatever its cause it requires urgent and efficient intervention and control. A seizure may:

1. Produce secondary insult following minor trauma, with a resulting disability far in excess of the original primary injury.

2. Indicate intracranial complications requiring skull xrays/CT scanning and surgical intervention. Seizure activity must be controlled both centrally and peripherally prior to transport, and may require the skills of an anaesthetist/paediatrician.

3. Febrile convulsions associated with head trauma require a reduction of temperature and treatment for the underlying pathology.

4. Require further subsequent investigation if it is the first manifestation of non-traumatic symptomatic or idiopathic seizures.

5. The risks of long term epilepsy should not be discussed in the emergency situation, because of the complex and multiple factors which operate in childhood from different causes and in different ages.

10. OUTCOME

10.1 Introduction

The outcome from isolated head injury may be difficult to predict, because of the complex and large number of variables which influence the final status of the patient. The emergency physicians responsibility is to ensure that the management decisions taken in the immediate post trauma period provide optimal conditions for recovery from the primary insult. Secondary insults should be prevented.

When head and cerebral injury is complicated by injury elsewhere the energies of senior and experienced staff, should initially concentrate on resuscitation, protection from further complication, and the identification of priorities of care.

Emergency staff having carried out initial care, rarely have any ongoing input, or knowledge of the outcome. For this reason the Paediatric Study was confined to identifying the type of injury, which accompanied head trauma, and the numbers.

10.2 Summary of Results

The Study confirms that head injury is very common in Accident and Emergency Departments and that:

Head injury alone occurs in	97%
The outcome is good at one month in	98%
Death occurred in	0.1%
Disability occurred in	0.2%

The severity of head injury and the other sites of injury are shown in Appendix 10.

When head injury is complicated by other injuries, particularly multiple injuries, the prognosis for the cerebral injury is less good.

Resuscitation and the priorities given to care are essential to cerebral protection from hypoxia and hypovolaemia and hypercarbia.

The frequency of complicating injuries are shown in Appendix 10.

10.3 Conclusions

1. The figures confirm that Casualty Medical Officers in a six month appointment will have limited opportunity to see and participate in the management of moderate and severe head injury, and even less where multiple injuries are present in the head injured child.

2. Senior experienced Accident & Emergency staff supported, where possible by a multidisciplinary team, including a paediatrician, and anaethetist, are essential to meet the infrequent demand, which requires skill, knowledge and experience of major rescucitation and cerebral protection.

11. ATTENDANCE PATTERNS

11.1 Introduction

Accidents happen at all times and without prior warning. Despite major A&E Departments offering 24 hour services, not all make special provision for children. Paediatric trained staff may not be available at all times. There is generally a reduction of staff between 20.00 hours and 00.08 hours.

Support staff, particularly for trauma victims, may be limited out of hours, and both availability and expertise reduced.

Delay to competent medical and surgical care can put the head injured child at risk, both in the prehospital and hospital setting. Apparently minor injury may progress rapidly to serious complications. Extradural haematoma is such an example. Clinical acumen, diagnostic imaging and access to neurosurgery are urgent priorities.

In serious head trauma inadequate control of the airway coma, hypoxia, hypercarbia and hypovolaemia may add further cerebral insult, to the primary injury(Miller and Becker, 1982 : Gentleman 1990 : Sharples et al 1990).

The presence of an intracranial haematoma mandates urgent access to neurosurgical facilities. Delay to evacuation has been identified as a source of mortality and morbidity(Reilly et al 1975 : Rose, Valtonen and Jennett 1977 : Mendelow et al 1983).

For these reasons the Monklands Study sought to measure the time from injury to arrival, and delays to neurosurgical care, when transfer was avoidably delayed. Two hospitals had on site neurosurgeons which potentially reduced access time and avoided inter hospital transfers, with the hazards involved(Sharples et al 1990).

The times and conditions in which head injury occurs will be affected by a wide variety of factors. Seasonal variations and weather conditions may be associated with activities related to environmental factors and particular locations. Winter sports, ice and snow may produce specific injuries and hazards. The summer months may encourage activities out of doors, which in children, may be associated with reduced adult supervision and more adventurous activities. Changing social patterns, and conditions within the community, may put children at risk in a variety of circumstances.

Mechanisation and motor vehicle usage increases the hazards to which children are exposed, particularly as pedestrians. Sport and leisure facilities available to children participating in a variety of activities may result in injury.

Speed of attendance following injury will be affected by the distance to the nearest medical facility, and the modes of transport available. Primary atttendances need to be identified from secondary referral which may modify attendance patterns and times. This Study was undertaken in hospitals serving predominantly urban communities. In two, Aberdeen and Poole, in particular, patients attended from more distant, rural locations. Almost 6,000 patients attended in six Accident & Emergency Departments. Only in Monklands Hospital were data collected throughout the year from January to December. An earlier survey of attendance in 1987 had identified the total patient numbers, and the proportion of head injuries, both adult and paediatric in a year. Table 11(i).

11.2 Summary of Results

a) Month of Attendance

Children with head injuries presenting in adult/mixed units formed 40% of all head injuries.
When data was collected over a full 12 month period the highest incidence was in the summer months.

b) Day of Attendance

Monday proved the business day across all the hospitals, but demands were substantial on all days. The ratio of male to female attendants was maintained in all periods.

c) Time of Arrival

The time of arrival showed that half of the children attended after 16.00 hours and attendance after 22.00 hours was not infrequent, and exposed children in adult units to an unfavourable and inappropriate environment.

1. Month of Arrival

The months of July and August coincide with school holidays, when there is the opportunity for unsupervised activity, often out of doors, and associated with more clement weather conditions and longer hours of daylight. In Monklands June and August were the busiest months. Staff were depleted by their personal vacation arrangements, with their children at home during school holidays. This identifies a requirement for medical and nursing staff levels, for increased demands.

2. Day of Arrival

When attendances are related to the day of the week, Monday is overall the busiest day. The male dominance is maintained for all days.
Saturday, Sunday and Wednesdays are days when General Practitioner surgeries are not available. We have no data on how many children attend the primary care service and which may never be notified to the hospital. The speed with which the majority of children are brought to hospital following injury, suggests there is a high incidence of GP bypass. It is rare to receive an urgent referral from a family doctor. The minority that are referred are not acute, and often present a request for skull xray. Injury may have occurred some days earlier. Symptoms may be atypical, and subsequently shown to be coincidental. Requests for skull xray is occasionally prompted by the discovery of an asymptomatic scalp swelling.

3. Time of Arrival

The demands on Accident & Emergency departments seeing adults, out of hours, may result in longer waiting times, both for assessment and investigation. Finite resources may put the child at a disadvantage.

Overnight observation beds may be required for clinical, social and geographical considerations. These may not be readily available out with dedicated paediatric units. The data from all hospitals show that half the children attend out with normal hours. This may be a reflection of changing social and domestic patterns.

The distribution of weekend and evening and night attendances has implications for the resources required. These include appropriately trained medical and nursing staff, particularly those with experience of paediatric and intensive care. There are similar requirements for diagnostic imaging technicians and interpretation of brain scans.

The attendance of children at night in adult units is not desirable, unless separate accommodation is available for treatment, and steps taken to protect them from unpleasant sights and sounds, which may be a feature of the A&E department out of hours. Priority given to a child may delay attendance to an adult in more urgent need.

Diagnostic imaging facilities may be less readily available at night and at weekends. This particularly applies to CT scanning which even where provided, may operate only in normal working hours. There is also reduced senior supervision, technical expertise and interpretative skills.

The demands in Accident & Emergency Departments seeing adults out of hours may result in longer waiting times for both assessment and investigation. Finite resources may put the child at a disadvantage. Overnight observation beds may be required for clinical, social and geographical considerations. These may not be available or ideal out with dedicated paediatric units.

4. Injury/Examination Intervals

The information recovered in this Study shows that three quarters of the children are brought for attention within two hours of the accident. An actively bleeding wound will prompt urgent attendance.

Delay in treatment following injury has been shown to affect outcome unfavourably, particularly if a mass lesion is present.

The data shows that patients and carers are not contributing to delays in the majority of children who presented with commendable speed. If delays are subsequently identified in the Accident and Emergency Department there may be implications for the resources provided, and the competence with which management decisions are made and implemented.

5. The Future

More information should become available with the extension of computerisation in A&E departments. Timing patient episodes and waiting times, will become routine. The location in which delays occur should be identified, and appropriate remedies taken to improve the quality of care. Triage on arrival should provide access to a doctor expeditiously, particularly in childhood.

The speed with which children are brought to hospital following head trauma is an indication of the seriousness with which parents and carers regard the condition. It clearly indicates that delays to neurosurgical intervention, where indicated does not lie with parents or emergency transport services. Waiting times in A&E departments generally are a cause for concern and political initiatives. It is essential that when the potential for delay is identified, urgent steps are taken to remedy the situation. More experienced doctors, out of hours, can influence rapid and accurate assessment and implement decisions.

The information contained in this chapter has clear implications for the Care of Children in Accident and Emergency Departments, the resources required and the general benefits of dedicated paediatric A&E Units, Section 12.

11.3 Conclusions

The Accident & Emergency Units contributing to this Study had many features in common. Not all that was learned could be applied to other units, particularly those defined within geographical and climatic conditions and resources. What was clear was that, in order to provide the highest standards of care the relevant resources must be available to meet demands in all major Accident & Emergency Departments treating children with recent head injury.

12. THE CARE OF CHILDREN IN ACCIDENT & EMERGENCY DEPARTMENTS

12.1 Introduction

It is estimated that more than two million children attend in Accident & Emergency Department annually. The majority of children are dependent on the staff of those departments who also see adults for their care.

Paediatric medical input is limited outside exclusively Paediatric Units. As recently as mid 1999 the Royal College of Paediatrics and Child Health voiced concerns on the failure to implement previously recommended standards for care.

Paediatricians, particularly physicians make a limited contribution. This is partly due to the physical separation from the A&E Departments and the small number of paediatric surgeons in District Hospitals.

There is a lack of provision of paediatric sessions. Only 12% of Departments have regular paediatric input. Shortages of junior medical staff make it difficult for any regular paediatric presence to be offered. Paediatric nurses, and appropriate physical facilities for children were inadequate.

When this Study was initiated, only three paediatric Accident & Emergency Departments had a full time Accident & Emergency Consultant, Sheffield, Liverpool and Dublin. Subsequently there have been further appointments. Paediatricians welcome this situation as ideal, and we were fortunate to be able to include Alder Hey in this Study together with the Royal Hospital for Sick Children in Aberdeen.

A comparison was made of the conditions and expertise provided for children who had sustained recent head injury in Monklands Hospital, a mixed adult/children's A&E Department and the Royal Aberdeen Children's Hospital including the use of Guidelines. See Appendix 12.

The A&E Department

(a) Environment

The A&E Department at Monklands had no separate waiting or treatment areas for children. Children were exposed in their emotive treatment episode to the activities of an adult unit. It was at night, that this proved particularly unsatisfactory. Diagnostic imaging provided no segregation from adults.

At Aberdeen the children had exclusive use of a specially designed children's department, appropriately furnished, decorated and stocked with play equipment and toys.

(b) Staffing

The Royal Aberdeen Children's Hospital was staffed with paediatric nurses. Monklands had one only 38 hours a week.

(c) The Medical Staffing

Medical Staff at Monklands at SHO level in the majority had no paediatric experience. Senior paediatricians had no responsibility for trauma, and provided no observation beds in the paediatric wards.

Children admitted at Monklands had access to single cubicles in the adult A&E Ward. There were no formal or physical provisions for parents to stay with their child.

The medical staff were SHO's from the A&E Department, but A&E Consultants with paediatric experience supervised care. Some children were electively transferred 10 miles into Glasgow to the Children's Hospital for observation.

(d) Transfers to Neurosurgical Care

At Aberdeen the Neurosurgical Unit was on the same campus.

At Monklands transfer was made by Intensive Care Ambulance, with medical escorts - 12 miles, to the Institute of Neurosurgical Sciences.

(e) Resuscitation

The child requiring resuscitation in Monklands Hospital, had dedicated resuscitation equipment in the General Resuscitation Room. Anaesthetic, and A&E Consultants, Surgical and Orthopaedic Specialists were available. Paediatric medical staff offered support and expertise.

Whilst the volume of experience could not match that of a dedicated paediatric hospital, no avoidable features or deficiencies were found.

The facilities at Royal Aberdeen Children's Hospital clearly were dedicated and comprehensive paediatric expertise was always available.

Analysis of the performance of the SHO's at Aberdeen, where the doctors were treating only children for between six and twelve months, showed they offered more

comprehensive diagnostic skills where head injury was not the only presenting problem, used less invasive diagnostic tests and requested fewer skull xrays.
The children's A&E Department had child orientated teaching, training and protocols and immediate access to senior paediatric opinion.
In Monklands training in a similar period, had to encompass all ages and all specialist adult illness and accidents.

12.3 <u>Conclusions</u>

1. It was sobering to have to admit that Jackson's criticisms, and the ongoing failure to meet recommendations for the care of children in hospital were applicable in Monklands District General Hospital. Whilst inevitably the conditions for the child with minor or moderate head injury warranted criticism and identified the need for improvement in the A&E Department and in the observation ward, the Study did not identify such inadequacies in resuscitation or transfer. The question however was raised as to whether children should, in the interests of quality of care, all be treated in dedicated paediatric units? If they are not, clearly there are major issues still to be addressed since the Court Report almost three decades ago, set standards for paediatric care in hospital. Overall care of children in adult departments is still far from ideal.

2. Whilst some improvements have been noted the recent Report of a Multidisciplinary group, Accident and Emergency Services for Children(1999) convened by the Royal College of Paediatrics and Child Health, confirms that the facilities and resources available do not meet the standards previously set and are appointing an Intercollegiate Advisory Group to oversee their recommendations in the future.

3. The availability of specialised courses in Paediatric Life Support should bring benefits, as more doctors gain access to instruction in practical procedures, and expand their knowledge of management of the seriously ill child.

13. CHILDREN ARE DIFFERENT TO ADULTS

13.1 Introduction

When the Author, with colleagues, published data on a comparison with adults, it was the first detailed analysis undertaken for head injured patients in A&E Departments. The prospective data from Monklands, 1984, was compared to pre-existing data held at the Institute for Neurological Sciences, Brookes et al(1990).

In the present Study covering six different groups of children, a much larger number 5,993, had more detailed information recorded.

13.2 Results

When the features of head injury are compared in this Study, with the children from the earlier study, the similarities and differences to adults are confirmed.

This more recent data identified the features in childhood, which statistically carry an increased risk of skull fracture.

In addition this Study not only indicated that children are different to adults, but different to children of different ages.

The value of skull fracture in predicting intracranial complications, including haematoma, Teasdale(1990), and in assisting doctors in decisions in the A&E Department is confirmed.

Skull fracture in children, as a tool for Triage for CT scanning remains controversial. It warrants admission for observation, where scanning in the young child presents technical difficulty, and is not mandated by other criteria.

Similarly it will alert the staff to the need for particular vigilance in observation, and identify the potential need for subsequent scanning where the facilities is not immediately available.

13.3 Conclusions

1. Children who sustain head trauma and attend A&E Departments are different to adults, but also from children of different ages.

2. They differ in their causes and mechanism of injury.

3. The scalp features often indicate less serious injury, with smaller numbers of children manifesting cerebral trauma.

4. The scalp injury and results of xrays are different in the varying age groups.

5. Less children lose consciousness than adults.

6. Children differ in their tendency to vomit after head trauma by age group and sex and compared with adults.

7. Headache may be less readily identified.

8. Fewer children attending A&E Departments are admitted to hospital than adults.

9. Children vary in their risk of skull fracture in different age groups and cannot be directly compared to adults.

10. Children vary by age in their risk of skull fracture.

11. Children less frequently develop intracranial haematoma than adults but also vary by age group, for this complication.

12. The relationship of intracranial haematoma and skull fracture indicates a lower risk in children, particularly infants.

13. Children develop complications of skull fracture not seen in adults.

14. Children develop complications unique to childhood.

The differences in admitted children and admitted adults was not examined in this A&E Study.

14. GUIDELINES FOR MANAGEMENT OF THE CHILD WITH A RECENT HEAD INJURY

14.1 Introduction

Guidelines issued for the care and management of head injury are primarily aimed at the staff of Accident and Emergency Departments and paediatric staff, including those in training. It is surprising therefore, that until relatively recently no agreed guidance had been offered for the management of children with recent head trauma.

Junior doctors know that they are in a very vulnerable position. They are subject to a variety of pressures. They may be persuaded by the views of parents and peers. They may be influenced by the age of the child, the mechanism of the injury and its cause, and the anxiety resulting from making a mistake. They may be fearful of litigation. Other medicolegal factors may operate, not directly related to clinical management.

The doctors may genuinely believe, based on their training and limited experience, that the result of an xray of the skull will enhance their ability to decide on the patient's treatment. They also know that it is often regarded as essential by the parent.

The Guidelines for requesting skull xrays following head injury, issued by the Royal College of Radiologists(1983) and subsequently updated, were not initially to be applied to children. It was known that these were influenced, at least in part, by generation of financial saving(Royal College of Radiologists 1981).

Clinical guidelines followed from a Group of Neurosurgeons(Briggs et al 1984) also to be applied to adults. There is no doubt that such advice may offer support to casualty doctors, particularly those who come to their appointments without prior experience.

It had been apparent to me that there were problems in the application of the adult guidelines. A few doctors in A&E Departments were not aware of the information, and clearly were not applying the advice. One of the problems I identified was the difficulty doctors, aware of the guidelines found in applying it to the individual patient, in the one to one situation. This was particularly so if the guidelines restricted their decision to request a skull xray, which they felt obliged to request. The doctors mistrusted guidance from remote august bodies, who might not share their problems, or support them in the event of error.

There was more confidence in local departmental protocols, supported by senior doctors, based on clinical rather than financial considerations.

My previous Studies had identified skull xray usage at Monklands Hospital. After instruction on the Guidelines, skull xray requests increased. Doctors for whatever reason, were reluctant to withhold skull xrays, when they had a reason for such a request.

14.2 Results Summary

The observed patterns of A&E doctors request for skull xrays, frequently did not conform to existing Guidelines at the time of this Study.

Direct interview showed some doctors were not aware of Guidelines. Some who were did not always apply them.
Doctors who were aware of Guidelines for adults after head trauma, did not think they should be applied to children.

Doctors preferred local protocols, because they were aware they emanated from their own Consultants and this offered reassurance (Royal Aberdeen Childrens Hospital particularly).

Doctors felt pressure to take skull xrays for reasons not covered in Guidelines such as parental pressure, and potential civil or criminal actions.

Doctors were not confident of support from distant august organisations, and were aware of their own professional responsibility to the patient.

Doctors were aware of controversies regarding management decisions, from experts in the field of head injury care, both neurosurgical and paediatric.

Doctors wished to exercise their own judgement in a one-to-one consultation with the patient/parent.

Media reporting of unfavourable outcomes made doctors feel vulnerable, as did the risk of personal criticism and litigation.

There was a more confident approach in the Paediatric A&E Department at Aberdeen, where all the doctors ongoing experience was with children. By contrast at Monklands Hospital, children were only a small part of the spectrum of head injury decisions, and the demands made upon them were for more wideranging.

The evidence presented in this Study and the literature review, shows that not only do doctors not always follow guidelines, but many requested skull xrays, and have a limited and potentially dangerous inability to interpret them correctly. It may be that not only are xrays being requested which might not be necessary, but which are not being correctly interpreted. False positive readings are leading to admissions and to CT scanning adding further expense and anxiety.

In view of the complex issues raised both in relation to skull x-ray and head injury management generally, I believe that

1. Guidelines should be drawn up by those who are prepared to use them and implement them.
2. A significant responsibility lies with the originators, both in offering support in implementation and in educating the users. There is a particular need to inform Junior Doctors of the underlying principles on which guidelines are based and the benefits likely to accrue to patients and to the staff caring for them.
3. The primary purpose of guidelines should be quality of patient care.
4. Account must be taken of the doctor/patient relationship on a one to one basis
5. Guidelines should not be seen to have as their primary purpose a reduction of costs.
6. Guidelines should not emanate from distant professional bodies, who do not have any responsibility for their application to the individual patients.
7. Guidelines should take into account the expectations of the wider public, including the patients and third parties with an interest in patient illness/injury outcome.
8. Guidelines are in my opinion a compromise. They replace effective and timely education. When converted into protocols they facilitate the use of lower grades of staff with savings in resources, and as a result limit independent thought and action, frustrating the educational development of the user.
9. Savings which may be achieved by the introduction of such measures should be re invested in education programmes. Guidelines may help the doctor in a difficult situation but modify freedom without removing responsibility, and in the long term may have harmful effects on medical education.

10. The risks of application or failure of application should be examined, ie audit should be undertaken.

11. Sustained compliance of effective guidelines should be assured.

12. There should be absolute cost efficiency, and not simply the transfer of expenses from one system of health care to another.

13. Guidelines should be acceptable to clinicians at all levels and in all disciplines with a responsibility for head injury management. Medical controversy in relation to management precludes acceptance of a sound medical code of practice, which would eliminate concern regarding legal considerations. If there are good medical reasons for a particular course of action and this is supported by guidance there can be no legal criticism, and no medical expert ready to promote an opposing view in the event of error. Unfortunately this is not the present position in practice.

The provision of a protocol does not guarantee its implementation. That and other information recovered in the course of this work has indicated a serious deficiency in translating well established knowledge into competent application. The reasons for this warrant further study. Teaching and experience and the specialist evolution of Accident and Emergency medicine may be crucial to future developments and improved standards of clinical care for the head injured patient.

In 1992 the Paediatric Life Support Group issued guidance for the management of children with head injury. They suggested that Radiography should be requested in the following circumstances:-

i) Loss of consciousness or amnesia at any time.
ii) Neurological symptoms or signs and CSF from the nose or ear.
iii) Suspected penetrating injury or foreign body.
iv) Scalp bruising or swelling.
v) Significant mechanism of injury.
vi) Children under 2 years of age.
vii) Difficulty in assessment.
viii) Non mobile infants.
ix) Inadequate history.
x) Alcohol intoxication!

HEAD INJURY IN CHILDHOOD – GUIDELINES   MARIE T BROOKES

The paediatric population at risk of sustaining a head injury is not a homogeneous group. The child under two years of age is more vulnerable to the effects of head trauma and skull fracture. The older child is not comparable to the adult, but moves towards similar patterns as the years pass. The data in this Thesis allows formulation of a policy as shown.

Skull X-rays - Indications

1. There should be a liberal use of skull x-rays in childhood.
2. Skull x-rays should be taken under two years of age following any head trauma or suspicions of abuse.
3. Scalp features of swelling, abrasion, contusion and galeal lacerations.
4. History of loss or any impairment of consciousness at any time.
5. Headache.
6. Headache, vomiting or both combined.
7. Any suspicion of foreign body, or
8. Penetrating injury.
9. Seizure.
10. Focal neurological signs, unless proceeding to CT Scan.
11. Impact onto a hard flat surface or blows with blunt implement.
12. Other significant high velocity injury, including road traffic accident.
13. Abuse.
14. Medicolegal - 3rd party litigation, and criminal activity.
15. At doctors discretion.

CT Scanning

1. Skull fracture. Infants may be the exception and observation only justified initially.
2. Impaired level of consciousness.
3. Deterioration of conscious level.
4. Focal neurological signs.
5. Severe headache/vomiting.
6. Recurrent vomiting.
7. Coma of unknown cause.
8. Abuse.
9. Multiple injury – unstable despite resuscitation.

Admission

1. Neurological observation.
2. Infants with skull fracture – not scanned.
3. Symptomatic relief.
4. Pending CT scanning.
5. Coincidental pathology – other injuries.

Transfer to Neurosurgery - after discussion.

1. Urgent intervention for a mass lesion.
2. Coma, without improvement, after resuscitation.
3. Positive CT scans requiring intervention.
4. Depressed fracture with CSF fistula or evidence of infection, or focal compression.
5. CT not immediately available, or without expert interpretation.

Guidelines formulated by specialists directly involved in, and held responsible for the care of children with head injury, are more likely to prove acceptable to, and be applied by junior medical officers. Resources can then be targeted to those who require them, and clinical care be delivered appropriately. The ultimate decision must be with the doctor in a one-to-one relationship with the patient, and who will be held responsible for the initial management.

The recent initiatives of the Scottish Intercollegiate Guideline Network have produced impressive guidelines over a variety of topics. These have resulted from evidence, expert input and wide consultation. This latter innovation may facilitate and improve implementation. Only sustained audit will confirm the success of these projects.

The SIGN Guidelines for head injured patients including children are still in preparation. Publication is anticipated in 1999. (Gentleman personal communication).

The formulation of Guidelines by experts in this particular field is to be commended. That must not however provide a false sense of security. The assumption that the advice is disseminated to those who require it, or that it is subsequently implemented, cannot be confirmed. I concluded that in relation to the management of head injured patients, there is no doubt of the need to ensure that doctors are in a position to offer the patients the highest standards of clinical care. There are serious problems with the practical application of knowledge which has been available for decades. The first question raised was "are methods of teaching effective?" Would doctors need guidelines if they had adequate knowledge on which to base their decisions? The guidelines would appear to be the provision of a degree of security in the absence of detailed knowledge, and experience. This might protect the patient and ensure a reasonable standard of care, but is less than ideal.

Clinicians responsible for Accident & Emergency Services have very different working conditions, workloads, staffing levels and opportunities for formal ongoing training programmes. Acute staff shortages in many areas of the United Kingdom at the present time make formal organised teaching difficult. The increasing use of doctors on a locum basis reduces continuity.

The frequency of exposure to positive skull xrays in a six month period clearly is inadequate to allow doctors to learn by experience. The evidence is that they do not do so. The presence of senior and experienced staff could reduce the overall requests for unnecessary skull xrays and the number of correct interpretations. The problems would appear to be the Casualty Officers tenure of office. In a six month period there is a vast range of clinical pathological material incorporated in the doctors work experience. Head injury though a significant part of that experience may not be the overall choice for further review at least from the doctors point of view. Even if the casualty officers expertise was enormously enhanced during the period of appointment, the onward movement to a totally different and perhaps unrelated specialty means that the doctor is not going to apply those skills again in the immediate future. This is perhaps why the registrar and senior registrar grades perform so well. They are committed to Accident & Emergency Medicine as a Specialty and the care of head injury is going to be a major part of their future life experience professionally. Though impractical at this present time, the provision of Accident & Emergency Services by doctors on a long term basis would clearly be in the interest of the head injured patient. Savings in unnecessary investigation might go some way to provide for this type of development?

14.3 Conclusions

Accident & Emergency medical offers require tuition on the need and indications for skull radiography, from seniors in their own Departments.

Formal teaching on the interpretation of skull xrays is required.

The detection of a skull fracture will influence management decisions.

The value of a fracture in triage for CT Scanning needs to be taught.

Patients who fulfill the criteria for CT Scanning should proceed to that investigation, without xrays.

Skull xrays may follow for depressed fracture and with more comprehensive radiology in abuse.

Skull fractures in asymptomatic children may warrant admission for observation rather than CT scanning of the brain.

Negative xrays do not reduce the requirement for an adequate history of the injury, and a full neurological assessment.

Skull fracture carries not only a risk of intracranial haematoma, but an increased incidence of CT abnormalities, which may not require neurosurgery, but subsequent evaluation in the child. Injury may affect subsequent progress and ability. It is an area in A&E medicine which has not been adequately addressed to date.

MTB's suggestions for guidance in children is offered based on experience, data derived from this Study, and from the literature.

This work is dedicated to children who seek help in our Accident & Emergency Departments and to the doctors

Who

Must

Never

Forget

That

THERE IS NO HEAD INJURY SO SEVERE THAT THE PATIENT MAY NOT RECOVER AND NONE SO SLIGHT THAT HE MAY NOT YET DIE

Hippocrates

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