ORIGINAL ARTICLE

Severe head injury in children: emergency access to neurosurgery in the United Kingdom

R C Tasker, K P Morris, R J Forsyth, C A Hawley, R C Parslow, on behalf of the UK Paediatric Brain Injury Study Group and the Paediatric Intensive Care Society Study Group

Emerg Med J 2006;23:519–522. doi: 10.1136/emj.2005.028779

See end of article for authors' affiliations

Correspondence to: R C Tasker, Cambridge University School of Clinical Medicine, Addenbrooke's Hospital, Hills Road, Cambridge CB2 2QQ, UK; rct31@cam.ac.uk

Accepted for publication 25 January 2006

Objective: To determine the scale of acute neurosurgery for severe traumatic brain injury (TBI) in childhood, and whether surgical evacuation for haematoma is achieved within four hours of presentation to an emergency department.

Methods: A 12 month audit of emergency access to all specialist neurosurgical and intensive care services in the UK. Severe TBI in a child was defined as that necessitating admission to intensive care.

Results: Of 448 children with severe head injuries, 91 (20.3%) underwent emergency neurosurgery, and 37% of these surgical patients had at least one non-reactive and dilated pupil. An acute subdural or epidural haematoma was present in 143/448 (31.9%) children, of whom 66 (46.2%) underwent surgery. Children needing surgical evacuation of haematoma were at a median distance of 29 km (interquartile range (IQR) 11.8–45.7) from their neurosurgical centre. One in four children took longer than one hour to reach hospital after injury. Once in an accident and emergency department, 41% took longer than four hours to arrive at the regional centre. The median interval between time of accident and arrival at the surgical centre was 4.5 hours (IQR 2.23–7.73), and 79% of inter-hospital transfers were undertaken by the referring hospital rather than the regional centre. In cases where the regional centre undertook the transfer, none were completed within four hours of presentation—the median interval was 6.3 hours (IQR 5.1–8.12).

Conclusions: The system of care for severely head injured children in the UK does not achieve surgical evacuation of a significant haematoma within four hours. The recommendation to use specialist regional paediatric transfer teams delays rather than expedites the emergency service.

In children with severe traumatic brain injury (TBI) after head injury there may be significant brain damage associated with space occupying effects of traumatic subdural and extradural haematoma. Therefore after an accident, in the stabilised, resuscitated, severely injured child, the initial priority is to identify those needing surgical evacuation of haematoma, and to transfer them safely to centres that provide such a service.^{1–3} Recent reports from the Royal College of Surgeons of England and the British Orthopaedic Association have also emphasised a time constraint, stating that “the system of care should achieve surgical evacuation of a significant haematoma within four hours”.^{1,2}

In the UK individual health regions have responsibility for a population in a specific geographic area. Some regions encompass conurbations or metropolitan counties, and others cover a mix of suburban and rural areas. Paediatric intensive care unit (PICU) and neurosurgical services are centralised and, in general, co-located with adult regional practices.^{4,5} In instances such as TBI where timeliness—within four hours—is considered a requirement, the system of care has to contend with the problem of patient access to emergency services. For example, in the Anglia region (a mixed rural and suburban area), the timings of care after severe TBI suggest that the four hour target for surgery is currently unworkable where road distance travel times between the primary receiving hospital and the regional centre are in excess of 45 minutes.⁶ We have undertaken a national audit of emergency access to specialist neurosurgical and intensive care services in the UK to determine, firstly, the scale of acute neurosurgery for severe TBI in childhood, and secondly, whether surgical evacuation for haematoma is timely.

METHODS

This report is based on data collected during the care of children with severe TBI that necessitated admission to an intensive care unit in the UK and Eire.⁷ Specific fields of data were collected so that we could answer our principal questions. In a rolling 12 month period from February 2001 to August 2003 data relating to 448 children in England, Northern Ireland, Scotland, and Wales were available. The rolling period was used in order to have an accurate assessment of the denominator. Children undergoing neurosurgery fell within a 12 month period. The West Midlands Multicentre Research Ethics Committee (MREC 01/7/27) and each of 28 local research ethics committees with participating units gave approval for the data collection.

Inclusion criteria

Any child under 16 years who was admitted to an intensive care unit with TBI as the primary reason for admission was considered eligible for this study. In all, 28 PICUs participated in the study and some data were obtained from a further 48 adult intensive care units. (To avoid inadvertent double counting, a cross-check between these two sets of data identified children who were transferred from an adult unit to a PICU.)

Data collection

The lead clinicians of each participating unit were responsible for collecting data on patients admitted to their unit. Data were entered on two pre-printed forms—one covering

Abbreviations: CT, computed tomography; GCS, Glasgow Coma Scale; PICU, paediatric intensive care unit; TBI, traumatic brain injury

admission and the first 24 hours and the other for subsequent hospital care until discharge. The information extracted from these forms for the purpose of this report was as follows: patient demographics; timing of injury and transfers to local hospital and regional centre; Glasgow Coma Scale (GCS) score, pupillary responses, and derangement in vital signs; findings from initial cranial computed tomography (CT), particularly presence of haematoma; and surgery performed.

Definitions, data handling, and statistics

The definitions used for physiological abnormality were as follows. A hypotensive episode was defined as systolic blood pressure below the sum of 50 mm Hg and double the age in years. A hypoxic episode was defined as partial pressure of oxygen in arterial blood below 60 mm Hg (8 kPa) or pulse oximetry haemoglobin oxygen saturation below 85%. Home postcode was used as a proxy for geographical location of injury, as in the UK most child pedestrian injuries occur within 500 m of home postcode⁸ and passenger casualties occur with an average distance of 2500 m of home postcode.⁹ The direct distance between this site and the regional neurosurgical centre at which the child received tertiary care was calculated and used in the analysis of transfer distance. Area based population density, based on the 2001 census,^{10, 11} was used to provide a density category according to standard descriptions of rural (dense or sparse), suburban (including industrial rural), and urban.¹² Descriptive statistics and comparisons between proportions have been used in the presentation of results.

RESULTS

Demographics and acute neurosurgery

Figure 1 shows the location of the children with severe head injury in the UK over a period of one year. The postcode data for Scotland and the southwest regions are incomplete, but

Figure 1 Map of the UK showing the location of children with severe head injuries. (Postcode data are incomplete for Scotland and the southwest regions.)

for the remainder of the UK the distribution of this series maps that expected for population density. Of the 448 children with severe head injuries, 91 (20.3%) underwent emergency neurosurgery (that is, on the calendar day of admission), and 69% of these children lived in urban areas, 21% in suburban areas, and 10% in rural areas. The child's sex was unknown in two cases, but there were 64 boys in the remaining 89. Median age at accident was 8.86 years (interquartile range (IQR) 4.59–12.83).

Cranial CT scan during the first 24 hours after injury revealed either subdural or epidural haematoma in 143/448 patients (31.9%). Overall, 66/143 patients (46.2%) with subdural or epidural haematoma underwent surgery. Eight of these 66 children had their haematoma evacuated after the first day of admission. During the time of this study the most common neurosurgical procedure for severe TBI was evacuation of haematoma (66/91, 73%), and individual centres performed it in a child a median of three times per year. Other procedures included elevation of depressed skull fracture (21/91, 23%), and decompressive craniectomy with or without brain tissue excision. One child in this series undergoing neurosurgery for TBI developed meningitis (6%, upper limit of the 95% confidence interval).

The system of care and access to acute neurosurgery

In the whole series of 448 children the median interval between time of accident and time of arrival at the local hospital was 36 minutes, and about 1 in 4 children took longer than one hour to reach hospital after injury. After presenting to hospital just over 70% of patients needed secondary transfer—that is, they were not taken directly to their regional centre from the scene of the accident. When this transfer was carried out by the first hospital the median interval between time of presentation and time of arrival at the regional centre was 4.3 hours. When the regional centre undertook the secondary transfer, using a specialist PICU transport team, the median interval was six hours. On average, use of a specialist transport team from the regional centre resulted in secondary transfer that was about 1.5 hours longer than if the local hospital moved the patient (local versus regional transfer, $p < 0.001$; two sample t test).

The distance between home and each individual regional centre to which children were transferred is summarised in Figure 2. The profile of the graph shows the variation in regional practice of centres around the UK. Metropolitan

Figure 2 Distance between home and the tertiary paediatric neurosurgical centre in children with severe TBI. Data for individual units (open circles) are ordered by increasing median distance from home. The solid black square depicts the median and interquartile range for the children undergoing surgical evacuation of haematoma.

centres, at one end of the spectrum, have their patients a median of 10–15 km away. At the other extreme, in rural regions, patients are a median of 50 km away. There are also centres in between these extremes that have a mixture of urban and rural practices, operating a median distance of 20 km, but an IQR of 5–80 km away.

In the 91 patients who had neurosurgery, distances and timings were no different to those already described. Across the UK, these children were at a median of 29 km (IQR 11.8–45.7) from their neurosurgical centre (fig 2, data plotted using the solid black square). The median interval between the time of injury and time of arrival at any hospital was 35 minutes (IQR 25–70). In the 58 patients who underwent evacuation of haematoma on the day of presentation, the median interval between time of accident and arrival at the surgical centre was 4.5 hours (IQR 2.23–7.73). Once in an accident and emergency department, 41% took longer than four hours to arrive at the regional centre. The majority (79%) of inter-hospital transfers in these cases were undertaken by the referring hospital rather than the regional PICU service. In the 10 cases where the regional PICU undertook the transfer none were completed within four hours of presentation to the accident and emergency department. In fact, the median interval was 6.3 hours (IQR 5.1–8.12).

Severity, anisocoria, and survival

The post-resuscitation GCS score of 58/91 (64%) neurosurgical TBI patients was 8 or below. Prior to arrival at the regional neurosurgical centre 85/91 (93%) patients were intubated and mechanically ventilated; 26% had had hypotension, and a further 5% had also been hypoxic. At least one non-reactive and dilated pupil was present in 34/91 (37%) patients. The duration of secondary transfer—the interval between arrival in the first hospital and arrival at the regional centre—was not faster in those who had lower GCS scores. In addition, even though the timings were shorter in those with abnormal pupillary responses (median 4.27 hours (IQR 2.68–5.46) versus 5.35 hours (IQR 3.8–12.48) (one tail Mann–Whitney, $p = 0.05$), half of these cases still took longer than four hours from presentation to get to the neurosurgical centre.

Overall, in the surgical patients, the outcome was known in 89/91 cases, 5 of whom (5.6%) died. In the 143 patients with subdural or epidural haematoma on CT scan, 2/66 (3%) undergoing surgical evacuation died compared with 18/77 (23.4%) deaths in those not having surgery (hypothesis test for proportions, $p < 0.01$). In the 18 non-surgical deaths, 9/18 patients had no midline shift associated with their haematoma. In the remaining nine patients with some midline shift, one had undergone cardiopulmonary resuscitation for cardiac arrest out of hospital, and a further five had bilateral fixed dilated pupils on admission. That left three patients who may have had a haematoma that needed surgical evacuation. When these cases are added to the 2/66 deaths in those undergoing surgical evacuation of haematoma (that is, 5/69), the estimate of mortality for acute subdural or epidural haematoma needing surgery could be as high as 7%.

DISCUSSION

In the UK acute services for children with head injuries are organised such that urgent supportive care is initiated locally and subsequent emergency care of intracranial complications is undertaken centrally.^{1–3 13} This study of the extent of acute neurosurgery for severe TBI in childhood and the timeliness of surgical evacuation for haematoma has two principal findings. Firstly, over 30% of such children undergo an emergency surgical procedure. Secondly, although these children receive, on average, urgent accident and emergency department care within 40 minutes of injury, in over 50% of those undergoing emergency evacuation of a haematoma, it

is not possible to transfer them to a neurosurgical centre within four hours of presentation.

National organisation and child access to emergency neurosurgery

In the UK the incidence of TBI in childhood necessitating intensive care is 5.6 per 100 000 paediatric population per year.⁷ Surgery is required in around a third of such children and, with regard to emergency evacuation of traumatic haematoma, the average regional caseload equates to three children per regional neurosurgical centre per year. Across the whole UK, the majority of these children require inter-hospital transfer for their neurosurgery, with an average distance of around 30 km.

Regional transport teams

Recent appraisals of the early management of patients with TBI from the Scottish Intercollegiate Guidelines Network,¹⁴ the Royal College of Paediatrics and Child Health,¹⁵ and the National Institute for Clinical Excellence,¹⁶ all recommend that the:

“transfer of a child to a specialist neurosurgical unit should be undertaken by staff experienced in the transfer of critically ill children—i.e., a (Regional) Paediatric Transfer Team”.

(However, the authors do acknowledge that the evidence informing this recommendation is weak.) Taking a pragmatic approach, it seems that in an emergency it takes around two hours to resuscitate, stabilise, and fully assess a critically ill child with TBI.⁶ If one considers the UK as a whole, it might seem reasonable to expect to see a child in a regional centre within four hours of presentation. For example, two hours of initial care followed by two hours for a regional PICU team to travel out to the child and transfer them back to the centre (that is, 30 km each way, or ~30 minutes each way, plus one hour leeway). However, the timings observed in this study far exceeded such an expectation. In general, use of a specialist regional team added an extra 90 minutes to the above estimate. In instances where emergency evacuation of haematoma was required involvement of the PICU transfer team contributed to the prolonged interval—between accident and emergency department presentation and arrival in the regional centre—such that it exceeded five hours in 7 out of 10 cases.

Delays in definitive care

The target time of “within four hours” is not being met in children requiring emergency neurosurgery after TBI, and the use of regional paediatric transfer teams is in fact leading to significant delays. Close inspection of the illustrations in this report indicate that, in order to reconcile the expert opinions contained within the various Royal Colleges and expert panel reports,^{1–3 14–16} more thought should be given to the design of our emergency system. Given the varied geographical regions found in the UK there is a need to improve the current system so that it works for children in metropolitan zones and those in more dispersed suburban and rural areas (that is, 31% of the children in this series). It will be necessary, first, to look at the possible reasons for the delay caused by the use of a specialist PICU transfer team. It may be, as we have previously suggested,⁶ to do with the logistics of mobilising staff and transport. Alternatively, it could be that these teams are only called at a late stage in emergency care, after patient stabilisation, investigation, and early management. Perhaps these teams have developed a way of working that is not time-critical as they were set up to deal with medical

conditions in which time to a specialist centre was not an imperative. Whatever the reason—and it is likely to be a combination—the limiting factors within the system will need to be examined more closely if we are to achieve emergency access to neurosurgery within four hours of injury and presentation for head injured children in the UK.

ACKNOWLEDGEMENTS

We are grateful to all the staff of PICUs who completed data collection forms, and to Dr K Rowan of ICNARC for supplying data on paediatric admissions to adult ICUs. N Hussain, H Sherry, and N Hallworth are thanked for database design, data entry, and preliminary data processing.

Authors' affiliations

R C Tasker, Cambridge University School of Clinical Medicine, Addenbrooke's Hospital, Cambridge, UK

K P Morris, Diana, Princess of Wales, Children's Hospital, Birmingham, UK

R J Forsyth, School of Clinical Medical Sciences (Child Health), Sir James Spence Institute of Child Health, Royal Victoria Infirmary, Newcastle upon Tyne, UK

C A Hawley, Division of Health in the Community, Warwick Medical School, University of Warwick, Coventry, UK

R C Parslow, Paediatric Epidemiology Group, Centre for Epidemiology and Biostatistics, Leeds Institute of Genetics, Health and Therapeutics, University of Leeds, Leeds, UK

This study was supported by grants from the Paediatric Intensive Care Society, Birmingham Children's Hospital Research Foundation and the Warwick University Research and Teaching Development Fund.

Competing interests: none declared

UK Paediatric Traumatic Brain Injury Study Steering Group

K Morris (Chair), R Appleton, M Crouchman, R Forsyth, C Hawley, M Marsh, P May, P McKinney, J Middleton, R Parslow, J Punt, T Ralph, R C Tasker.

Participating centres and investigators

Addenbrooke's Hospital (R C Tasker), Alder Hey Children's Hospital (R Sarginson), Antrim Hospital (A Ferguson), Beaumont Hospital, Dublin (E Keane), Birmingham Children's Hospital (K Morris), Bristol Children's Hospital (J Fraser), City General Hospital, Stoke (J Alexander), Derriford Hospital, Plymouth (S Ferguson), Great Ormond St Hospital (M Kenny, D Lutman), Guy's Hospital (A Durward), Hull Royal Infirmary (H Klonin), John Radcliffe Hospital (A Shefler, C Killick), King's College Hospital (D Prior, L Edwards, Y Egberongbe), Leeds General Infirmary (T Chater, M Darowski), Leicester Royal Infirmary (P Barry), Queen's Medical Centre, Nottingham (P Khandelwal), James Cook University Hospital (A Robinson), Newcastle General Hospital (R Forsyth), Royal Belfast Hospital for Sick Children (B Taylor), Royal Berkshire Hospital (A Maunganidze), Royal Devon & Exeter Hospital (J Purday), Royal

Hospital for Sick Children, Edinburgh (M Lo, D Simpson), Royal Hospital for Sick Children, Glasgow (P Cullen), Royal London Hospital (P Withington), Royal Manchester Children's Hospital (D Stewart, M Samuels), Royal Preston Hospital (P Tomlin), Sandwell Hospital (J Bellin), Sheffield Children's Hospital (T Ralph), Southampton General Hospital (C Boyles), Southern General Hospital, Glasgow (D Snaddon, A Wagstaff), St Georges Hospital (S Skellett), University Hospital of Wales (M Gajraj), Walsgrave Hospital (M Christie), Walton Centre for Neurosurgery (E Wright).

REFERENCES

- 1 **The Royal College of Surgeons of England and the British Orthopaedic Association.** *Better Care for the Severely Injured*. London: Royal College of Surgeons of England, 2000.
- 2 **The Royal College of Surgeons of England.** *Report of the Working party on the Management of Patients with Head Injuries*. London: The Royal College of Surgeons of England, 1999.
- 3 **The Society of British Neurological Surgeons.** *Safe Neurosurgery 2000*. London: Society of British Neurological Surgeons, 1999.
- 4 **Department of Health.** *Paediatric Intensive Care "A Framework for the Future"*. Report from the National Coordinating Group on Paediatric Intensive Care to the Chief Executive of the NHS Executive. London: Department of Health, 1997.
- 5 **Shann F.** Australian view of paediatric intensive care in Britain. *Lancet* 1993;**342**:68.
- 6 **Tasker RC, Gupta S, White DK.** Severe head injury in children: geographical range of an emergency neurosurgical practice. *Emerg Med J* 2004;**21**:433-7.
- 7 **Parslow RC, Morris K, Tasker RC, et al.** Epidemiology of traumatic brain injury in children receiving intensive care in the UK. *Arch Dis Child* 2005;**90**:1182-7.
- 8 **Hewson P.** Deprived children or deprived neighbourhoods? A public health approach to the investigation of links between deprivation and injury risk with specific reference to child road safety in Devon County, UK. *BMC Public Health* 2004;**4**:15-24.
- 9 **Abdalla IM, Raeside R, Barker D, et al.** An investigation into the relationships between area social characteristics and road accident casualties. *Accid Anal Prev* 1997;**29**:583-93.
- 10 **General Register Office for Scotland.** 2001 Census: Standard Area Statistics (Scotland) [computer file]. ESRC/JISC Census Programme, Census Dissemination Unit, MIMAS (University of Manchester).
- 11 **Office for National Statistics.** 2001 Census: Standard Area Statistics (England and Wales) [computer file]. ESRC/JISC Census Programme, Census Dissemination Unit, MIMAS (University of Manchester).
- 12 **Dorling D, Atkins D.** *Population Density, Change and Concentration in Great Britain 1971, 1981 and 1991*, Studies on medical and population subjects No. 58, 1995. London: HMSO.
- 13 **Seeley HM, Maimaris C, Carroll G, et al.** Implementing the Galasko report on the management of head injuries: the Eastern Region approach. *Emerg Med J*, 2001;**18**, 358-65.
- 14 **Scottish Intercollegiate Guidelines Network.** *Early Management of Patients with a Head Injury*. Edinburgh: SIGN, Scottish Intercollegiate Guideline 46, 2000:36.
- 15 **Royal College of Paediatrics and Child Health.** *Clinical Appraisal on the SIGN Head Injury Guideline*. London: Royal College of Paediatrics and Child Health, 2001.
- 16 **National Collaborating Centre for Acute Care.** *Head Injury: Triage, Assessment, Investigation and Early Management of Head Injury in Infants, Children and Adults*. London: National Health Service, National Institute for Clinical Excellence, 2003:74.