ORIGINAL ARTICLE

Severe head injury in children: geographical range of an emergency neurosurgical practice

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Objective: To determine the timings of regional transfer for emergency neurosurgery and intensive care after severe head injury in children, and the effective operational range of a regional service.
Design: Prospective observational study of admissions to a regional paediatric intensive care unit (PICU).
Setting: East Anglia region in England, January 2000 to December 2001, where 18 referring hospitals are within two hours road transit time from the centre.
Patients: 69 severely head injured children (52 boys and 17 girls, aged 8.4 (3.6 to 12.5) years).
Main outcome measures: Time interval between injury and arrival at first hospital (primary transfer); timing between arrival at first hospital and arrival in PICU or the operating theatre (secondary transfer).
Results: Arrival in one of the 19 accident and emergency departments occurred (median, IQR) within 48 (35 to 70) minutes of the accident. After arrival, the interval of secondary transfer was 4.4 (3.2 to 5.8) hours. Children rarely received their surgery within four hours of injury; for this to occur, the geographical range of this regional practice would need to be restricted to those hospitals within about 45 minute road transit time from the centre.
Conclusions: Good evidence supporting the recommendation that acute neurosurgery for the evacuation of a haematoma within four hours of injury is still scarce. The timings of care after an accident suggest that this guideline is unworkable in regions covering areas with road distance travel times in excess of 45 minutes.

Severe head injury remains a common cause of disability in children with some morbidity potentially preventable.[1 2] The recent report from the Royal College of Surgeons of England and the British Orthopaedic Association has thus emphasised three key points about emergency care.[3] Firstly, that acute management must be in accordance with their current recommendations.[4 5] Secondly, that the priority of those first receiving such patients must be to recognise the potential intracranial complications that will necessitate neurosurgery and neurointensive care. And last, that ''the system of care should achieve surgical evacuation of a significant subdural haematoma within four hours''[3] or that ''life-saving decompressive surgery must be available for all patients who require it within four hours of injury''.[4]

We have undertaken an observational study of severely head injured children admitted to our regional paediatric intensive care unit (PICU) to determine, firstly, the interval from injury to initial hospital care and, secondly, the effective operational range of our paediatric practice given the above recommendations on timing of surgery.

METHODS

All children with an accidental head injury admitted to the regional PICU at Addenbrooke's Hospital during the two years, January 2000 to December 2001, were included in this prospective study. We excluded cases of non-accidental head injury. This project was registered with our hospital audit office, and the outcome component had approval from the local research ethics committee.

We looked at the duration of two intervals occurring after the child's accident. These contiguous intervals were: ''primary transfer'', the period between the time of the accident and arrival at one of 19 accident and emergency (A&E) departments in the region (fig 1); and, ''secondary transfer'', the period between the arrival in the A&E department and arrival in the PICU or neurosurgical operating theatre. These timings were collected from ambulance, A&E, PICU, and neurosurgical theatre records, and on occasion a clinical history of the incident. To facilitate complete data collection we used a form that was filled in at the time of referral and admission. We first developed and piloted this form in 1999. Our experience is that complete data can be identified providing the quantity is not overly ambitious, and that the responsibility for data collection is limited to key workers who are available at the time of patient referral and admission.

The road transit time from each hospital referring patients to Addenbrooke's Hospital (fig 1) was calculated on the Automobile Association (AA) web site in 2000 and 2001 (see http://www.theaa.com). We chose this analysis as these hospitals transferred too few patients for us to estimate accurately that site's average ambulance transfer time. In fact, taking our last 45 transfers from the 18 hospitals we have found that the mean difference between the AA estimate and the actual local emergency ambulance time is 4 (−6 to 16) minutes (median (interquartile range)).

Glasgow outcome scale (GOS) category[6] was assessed using a postal questionnaire to the child's general practitioner at least six months after hospital discharge. Outcome was then dichotomised into favourable (comprising GOS categories good and moderate disability) and unfavourable states (comprising GOS categories severe disability and vegetative state in survivors, and death).

FINDINGS

Over the two years we treated 69 acutely head injured children (52 boys and 17 girls, aged 8.4 (3.6 to 12.5) years). Twenty seven of 69 patients had a post-resuscitation Glasgow coma scale score (GCS) 8 or below. At the time of subsequent

Abbreviations: PICU, paediatric intensive care unit; GCS, Glasgow coma scale; GOS, Glasgow outcome scale

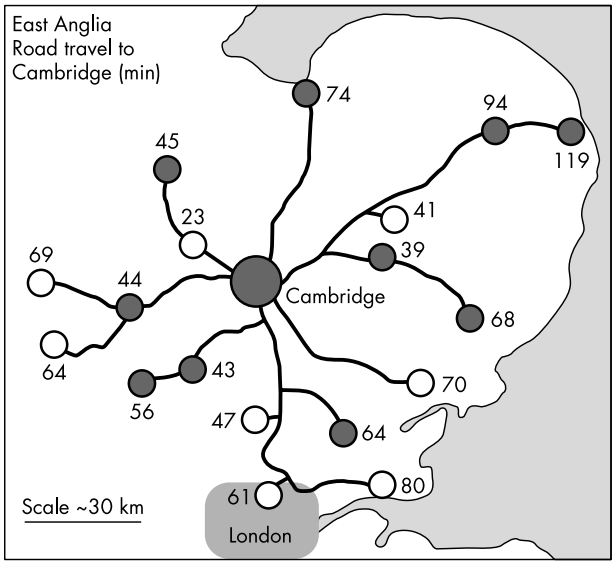

Figure 1 Road distance travel to Addenbrooke's Hospital, Cambridge, in minutes from the 18 centres referring severely head injured children. The hatched circles denote those centres able to ''image transfer'' head scans to the centre.

referral to the PICU 63 of 69 patients were intubated and all but one was transferred by the referring A&E department. Twenty three of 69 patients required an operation and, of these, 13 children needed their surgery shortly after admission for evacuation of a haematoma. Overall, 7 of 69 patients had unfavourable outcomes, with four deaths. We were unable to follow up seven children—none had had surgery and none were in the unfavourable category at the time of hospital discharge.

Primary transfer

For the whole series arrival in an A&E department occurred within 48 (35 to 70) minutes of accident. Twenty six patients (38%) arrived 60 minutes, or longer, after their accident. The whole region's primary transfer interval was no different to that of the 14 of 69 patients first seen in Addenbrooke's A&E department (48 (34 to 61) minutes).

Secondary transfer

In the 14 of 69 patients first seen in Addenbrooke's A&E department it took 2 (1.2 to 2.8) hours for children to undergo initial assessment, imaging investigations, treatment, and transfer to either the operating theatre or the PICU. In the remaining 55 of 69 patients referred from the region's other 18 A&E departments, the secondary transfer time also included the time taken for ambulance travel to Addenbrooke's Hospital. In each case local ambulance services were used. On one occasion, a transport team travelled by taxicab from Cambridge to the referring A&E department and returned with the child using the referring hospital's ambulance service.

Figure 2 summarises the region's secondary transfer time in relation to road transit time from Addenbrooke's Hospital for all 69 patients. (The patient transferred by the Addenbrooke's team was at the hospital located 94 minutes road transit time from Cambridge; this patient's secondary transfer time of 14.7 hours has been included in the analysis, unchanged). Nineteen of 69 patients were seen in the eight referring A&E departments without an image transfer facility; their secondary transfer times were 4.3 (3.5 to 6.3) hours. (On regression analysis, the secondary transfer

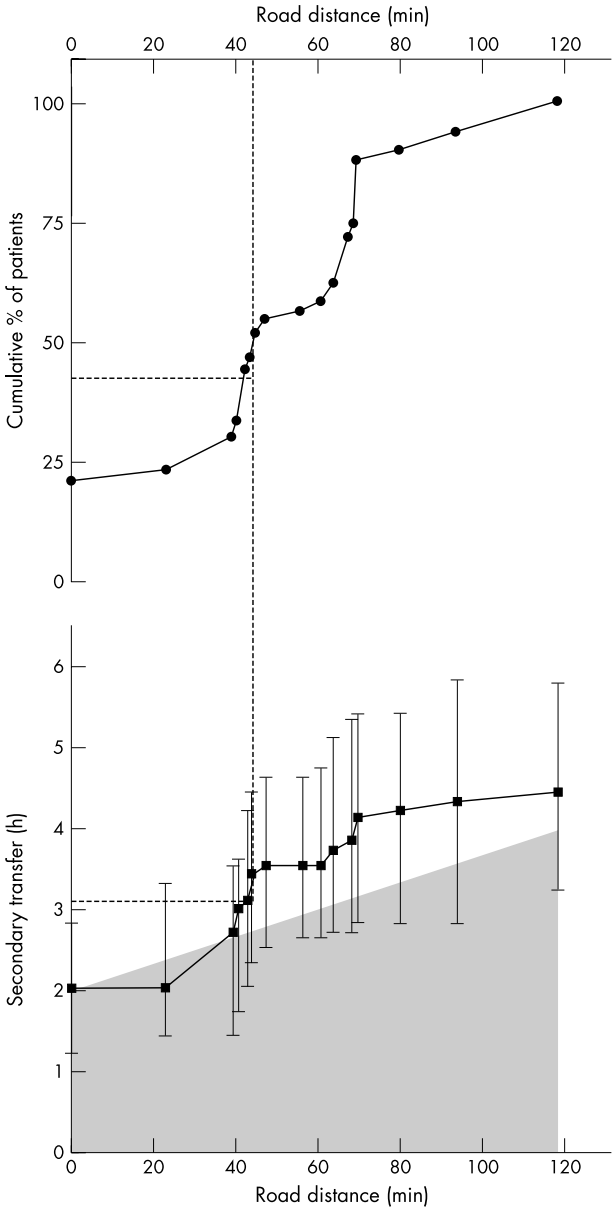

Figure 2 Combined graphs plotting the cumulative percentage of patients (upper panel) and the secondary transfer times (lower panel, median and IQR) by road distance travel time from Addenbrooke's Hospital. Each point represents all patients managed within that zone. The hatched area shows the expected or ''ideal'' times for our regional system (see text for details).

time was not influenced by the lack of availability of electronic image transfer).

The hatched area of the lower graph in figure 2 shows the ''ideal'' timings assuming that there were no differences around the region in A&E department timings, compared with the Addenbrooke's A&E department, and that arrangements for transfer from the 18 centres was not delayed. By taking all of the transfers as a proxy for seeing whether our regional system could achieve the recommended surgical timings we note that the median time is close to four hours. However, in relation to increasing road transit time from the centre, there is some deviation from the ideal around the middle of the region. For example, given the median time of 48 minutes for primary transfer, we see that secondary transfer within 3.2 hours (that is, total of four hours from the accident) was, on average, restricted to those referred from

within about 45 minutes road transit time from our centre. This range is more restricted than the 72 minutes (48 minutes primary transfer+120 minutes A&E department care+ 72 minutes = 4 hours) road transit time one would predict if the model for our system performed as expected; $p<0.001$, one sample test for the observed proportion of four hours spent in transit versus the proportion expected if the null hypothesis were true. Also, the patients covered by this zone comprised only 45% of our practice. If we consider secondary transfer less than four hours, then, on average, it can only be achieved in those referred from within a 70 minutes road transit time from Addenbrooke's Hospital.

Emergency neurosurgery

Thirteen of 69 patients needed surgical evacuation of a haematoma (subdural or epidural). Five patients were seen after a period of hospital observation or temporary discharge lasting between 12 and 58 hours after first presentation. Outcome in these patients was favourable. The remaining eight patients were referred at the time of initial presentation to A&E when they had GCS 7 (3–13)—six of these patients had one pupil fixed and dilated. In these eight patients the secondary transfer interval was 4.1 (3.4 to 5.1) hours. The interval between injury and being seen on PICU or theatre was 5.4 (4.1 to 9.9) hours, with only one patient being seen within four hours of injury. Seven of these patients had favourable outcome, and the eighth survives with unfavourable outcome. The proportion of unfavourable outcome in these children was no worse than that seen in the other 61 patients (hypothesis test on one of eight compared with 6 of 61 gave a difference between the proportions of 0.2 standard errors away from the hypothesised difference of zero).

DISCUSSION

Acute services for head injured children in the Eastern Region is organised such that urgent supportive care is initiated locally and subsequent emergency care of intracranial complications is undertaken centrally.[7] This study of our experience has two principal findings. Firstly, that such children are, on average, receiving urgent A&E department care within 48 minutes of injury. Secondly, given current neurosurgical recommendations,[3–5] the effective operational range for the emergency regional service would be limited to hospitals within about 45 minutes or 70 minutes road transit time from our centre. The latter depending on which guideline you chose to apply—four hours from injury or four hours from initiation of hospital care respectively.

The golden hour

The golden hour principle applied to the care of critically ill children is that success is dependent on a team approach using well rehearsed, systematic management protocols that can be implemented within the first hour after injury.[8] This study indicates that, in just over one third of our region's children with severe head injury, the first hour after an accident is spent outside the domain of hospital A&E department care. We do not know how much prehospital care our patients receive, but we believe that this finding warrants further study to examine whether morbidity could be limited by more timely interventions.

A&E practice and transfer

The analysis in this study is focused on the cumulative experience of all patients managed within the various perimeters determined by increasing road transit time from the regional centre, rather than the performance of individual A&E departments. We have found that once a child with severe head injury arrives in our centre's A&E department it takes about two hours for completion of assessment, imaging, and acute treatment before transfer for ongoing management. If we assume that A&E department timings are similar across the region then, on average, for the total area covered by our emergency practice (with maximum road transit time less than two hours), we would expect to meet the recommended limit of four hours surgical target time.[3 4] As expected, taking the whole region, this target was possible for half the population requiring our service. Although it could be argued this goal should be attained in at least 75% of the population—which is our position. However, figure 2 shows that this criterion would severely restrict our effective range to about 41 minutes road transit distance from Cambridge.

Traumatic haematoma

An important assumption underlying this study is that attendants' clinical perception or behaviour did not influence the timings. That is, all patients were considered in need of immediate transfer, and that the results of imaging or discussion about the patient's condition did not lessen the exigency for transfer. (Of note, 8 of 18 referring centres did not have electronic ''image transfer'' connection with Addenbrooke's Hospital). On this basis, we examined performance in the whole series as proxy for seeing whether our region could achieve the neurosurgical target times[3–5] were they to be required. Our approach may be flawed. Teams may have met the target had they known that the system was being observed. Alternatively—which is our contention—significant deviation reflected aspects of the regional system that warrant further exploration. For example, this analysis showed that the operational range for the emergency regional service would be limited to hospitals within about 45 minutes road transit time from our centre if we needed to ensure that patients were received within four hours of injury. This restriction, compared with the expected time (see above), is because of the sigmoid shape of the cumulative data graph (fig 2, lower panel); in particular, when covering the intermediate zone of our region. We have not explored the reasons for this feature, but it does warrant future study. One explanation could be that there are deficiencies in our methods. Alternatively, there may be important ''factors'' in the system acting at a local level, such as the logistics of cross boundary ambulance transfer. The region we cover is served by five Ambulance National Health Service Trusts.

In fact, only eight patients actually needed acute surgery within four hours. Even in these children, our performance was similar to that in the whole series—only one child reached the centre within four hours of injury and four children had secondary transfer times exceeding four hours. There are too few patients in this category to study why they were apparently failed by the regional service. We suspect that whatever underlies the factors described in the previous section of this discussion, applies also to these patients.

However, what does surprise us is that, despite failing to meet the recommendations for timing of surgical evacuation, the outcome was classed ''unfavourable'' in just one child. Of course, we have used only a crude instrument to assess outcome and the scale's limitations[9] and the size of our series may mask some significant morbidities. It is also possible that children may behave very differently to traumatic head injury, compared with the response and morbidity expected in adults—the reference population for most of our clinical preconceptions.[2 10] For example, in adults with severe head injury, acute subdural haematoma is associated with 90% mortality if evacuated more than four hours after injury and only 30% mortality if evacuated earlier.[11] If subdural evacuation is done within two hours after injury, one study reported a 70% decrease in mortality.[12] Alternatively, it could be that this adult evidence contributing to the current

recommendations about timing of surgery is largely anecdotal. In fact, more recent clinical reviews suggest that outcome is more related to severity of injury and the ability to acutely control intracranial pressure.[13–15] Hence, our outcomes, despite the timings, could be attributable to more optimal resuscitation by A&E department teams before transfer, rather than their emphasis on hastiness of transfer.

Regionalisation and geographical operational limit

Population based regionalisation of paediatric neurosurgical and neurointensive care services is necessary because of the numbers of patients needed for a viable and sustainable clinical practice.[16 17] In practice many such services, like Addenbrooke's Hospital, are co-located in adult regional centres. However, one consequence of such centralisation for mixed suburban and rural regions (such as the Eastern Region), in contrast with those encompassing conurbations or metropolitan counties, is that the provision of an emergency practice has to contend with the problem of patient access, particularly if timeliness—within four hours—is a key requirement.

So far, we have described potential limits to the operational range of our emergency regional paediatric service were we to comply with current recommendations about the timeliness of acute surgery (that is, about 70 or about 45 minutes). However, the operational limit of the service would also be limited to about 45 minutes road transit range if patients had to be transferred by ''staff experienced in the transfer of critically ill children—that is, a (Regional) Paediatric Transfer Team'', as suggested by both the Scottish Intercollegiate Guidelines Network[18] and the Royal College of Paediatrics and Child Health.[19] For example, if a PICU transport team were required to travel out from our centre and transfer the child back there would be at least a potential doubling of each referral site's road distance times. The possible effect of this change in practice was estimated from figure 2; but it is of note that, the one instance in this series where PICU transport occurred, the secondary transfer time far exceeded four hours. Even in other, regional paediatric transport series (for the non-head injured) there are similarly long transfer timings, for example, 6.2 (2.2 to 10.3) hours for transfers to west London.[20] Taken together with the discussion about A&E practice and transfer (see above), these data indicate that if the achievement of all recommended guidelines[3–5 9 10] was the target for good practice then the geographical range for a service such as ours would need to be limited to referrals up to about 45 minutes road distance away; currently comprising just one half of our practice.

Therefore, organisation of services with the above recommendations and time constraint is, in our opinion, unworkable except, possibly, in metropolitan zones. So are there any pragmatic solutions? Before discussing our local experience, it is important to say that we do support both the tenet and scope of the current recommendations. However, we wonder whether the absolute timing of subdural blood removal is overly peremptory given the nature of the published evidence and the reality of our current regional emergency organisations. It may be that an emphasis on good resuscitation and supportive care, with the avoidance of hypoxia and hypotension, would lead to better outcomes and that haste is not the only factor. Hence, a secondary transfer time of more than four hours may not have to be viewed as a failure of the service. That said, in Cambridge, we have set in place five operational features of our practice that, we believe, go some way in achieving the aims of the recommendations.

Firstly, we have a regional group who reviews, every two years, our practice and protocols. This group is composed of representatives from each of the referring hospitals, the neurosurgery service, the PICU, Addenbrooke's A&E department, and a senior nurse coordinator. Secondly, we have discussed with each of our referring hospitals the post-resuscitation, intensive care of severely head injured children. We have tried to establish a standard approach so that, irrespective of where the child is sited, intensive care—as though on the PICU—could be initiated. Our experience is that most hospitals and referring clinicians agree with these regionally determined protocols. Thirdly, we have a procedure for patient referral. For the referring clinician this includes, who to call first, what phone numbers to use, and what to do if that fails or if there is a delay or no response. For the PICU team this includes, who to notify and what to do if there is no available bed. Fourthly, we insist on the referring team transferring the head injured child to our centre. Our main concern is that the long transfer times of regional transport teams are such that patients may be at risk of poor outcome should further deterioration or a herniation syndrome occur in association with traumatic haematoma. Lastly, our philosophy is that the undertaking of urgent neurosurgery is not linked to the availability of a PICU bed. That is, if a child needs acute surgery then they should be transferred, primarily for surgery, and taken to theatre before admission to PICU. Any problems with PICU beds should be dealt with as a secondary issue; usually, special arrangements can be made during the period of the transfer and operation. A corollary of this scheme is that if a child needs lifesaving neurosurgery in an A&E department then, initially, time may be better spent transferring the neurosurgeon to the child rather than vice versa. In the past four years (that is, 1999) this process has had to be undergone on just one occasion to a hospital 70 minutes from our centre that did not have electronic image transfer capabilities. The consultant neurosurgeon was transferred by helicopter and the child came to the regional PICU postoperatively. As yet, in our location, we do not consider air transport of all critically ill children to be a more practical and timely option.

In conclusion, our study has identified important information about regional, emergency head injury services for children. The timings of A&E department assessment and subsequent transfer to the regional centre suggest that current surgical guidelines are unworkable in regions covering areas with road distance times in excess of 45 minutes.

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CONTRIBUTORS

Robert Tasker initiated the project. All three authors contributed to the design and data collection of the study, and all are guarantors for the study.

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REFERENCES

1 **Carter YH**, Jones PW. *Mortality trends in UK 1979 to 1997.* London: Child Accident Prevention Trust, 2000.
2 **Sharples PM**, Storey A, Aynsley-Green A, *et al*. Avoidable factors contributing to death of children with head injury. *BMJ* 1990;**300**:87–91.
3 **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.

4 **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.
5 **The Society of British Neurological Surgeons**. *Safe neurosurgery 2000*. London: The Society of British Neurological Surgeons, 1999.
6 **Jennett B**, Bond M. Assessment of outcome after severe brain damage. A practical scale. *Lancet* 1975;i:480–4.
7 **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.
8 **Nichols DG**, Yaster M, Lappe DG, Haller JA, eds. *Golden hour: the handbook of advanced pediatric life support*. 2nd edn. London: Mosby-Year Book, 1996.
9 **Robertson CMT**, Watt JM, Joffe AR, *et al*. Childhood morbidity after severe traumatic brain injury: increased detection with the Multiattribute Health Status Classification. *Pediatr Crit Care Med* 2001;**2**:145–50.
10 **Teasdale GM**, Murray G, Anderson E, *et al*. Risks of acute traumatic intracranial haematoma in children and adults: implications for managing head injuries. *BMJ* 1990;**300**:363–7.
11 **Seeling JM**, Becker DP, Miller JD, *et al*. Traumatic acute subdural hematoma: major mortality reduction in comatose patients treated within four hours. *N Engl J Med* 1981;**304**:1511–18.
12 **Haselsberger K**, Pucher R, Auer LM. Prognosis after acute subdural or epidural hemorrhage. *Acta Neurochir* 1988;**90**:111–16.
13 **Willberger JE**, Harris M, Diamond DL. Acute subdural hematoma: morbidity and mortality related to timing of operative intervention. *J Trauma* 1990;**30**:733–6.
14 **Willberger JE**, Harris M, Diamond DL. Acute subdural hematoma: morbidity, mortality, and operative timing. *J Neurosurg* 1991;**74**:212–18.
15 **Dent DL**, Croce MA, Menke PG, *et al*. Prognostic factors after acute subdural hematoma. *J Trauma* 1995;**39**:36–42.
16 **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.
17 **Shann F**. Australian view of paediatric intensive care in Britain. *Lancet* 1993;**342**:68.
18 **Scottish Intercollegiate Guidelines Network**. *Early management of patients with a head injury*. Edinburgh: The Scottish Intercollegiate Guidelines Network, 2000.
19 **The Royal College of Paediatrics and Child Health**. *Guidelines for good practice—early management of patients with a head injury*. London: The Royal College of Paediatrics and Child Health, 2001.
20 **Britto J**, Nadel S, Maconochie I, *et al*. Morbidity and severity of illness during interhospital transfer: impact of a specialised paediatric retrieval team. *BMJ* 1995;**311**:836–9.