treatment during the journey rather than relying on the speed of the ambulance. The prolonged periods away from the base hospital suggest that a transfer service with medical staff covering emergencies within the hospital would be unsatisfactory. The group consists of registrars who have completed their fellowship examinations (two anaesthetists and one surgeon) whose main clinical responsibility is that of the mobile intensive care unit. At least one, and usually two, of the team are available for transfers 24 hours a day without depleting emergency cover at the base hospital.

The increasing use made of the service (table I) partly represents an increased awareness of its existence and appreciation of the requirements for safe transfer. This trend should be taken into account when planning secondary transfer services. Although the recent increase has been mainly in local transfers the variety of destinations and cross boundary flow is greater than in previous years.[2] The transfer of patients to liver and cardiac transplant units is a recent phenomenon, with important funding implications. These transfers are costly in time and resources and require critical evaluation. The mobile intensive care service is funded by the Greater Glasgow Health Board. At present, no per head reimbursement is provided by other health boards, but detailed costs are currently being calculated before implementation of the government white paper.

A secondary transfer service should be tailored to the geography, population, and distribution of services in its area. Glasgow has special needs, firstly, because it is a referral centre for large sparsely populated areas of Scotland, and, secondly, because its regional services are distributed in different hospitals around the city. This contrasts with the recommendations for regional trauma units,[9] but the group does allow safe transfer among hospitals.

The favourable mortality in the over 75 age group (table VI) implies that age alone should not exclude patients from transfer for intensive care. The higher mortality in patients transferred from other intensive care units is interesting. Patients already receiving intensive care in whom deterioration precipitates transfer to a more specialist unit may well have a poorer prognosis than those transferred at an earlier stage of disease. Despite the absence of deaths in transit, the high eventual mortality in some patient groups reinforces the need for accurate prediction of outcome[10] if inappropriate transfer is to be avoided.

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Avoidable factors contributing to death of children with head injury

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Abstract

***Objective*—To assess the incidence of potentially avoidable complications contributing to death of children with head injuries.**

***Design*—Retrospective review of children who died with head injuries from 1979 to 1986 from data of the Office of Population Censuses and Surveys, Hospital Activity Analyses, case notes, coroners' records, and necropsy reports.**

***Setting*—District general hospitals and two regional neurosurgical centres in Northern region.**

***Results*—255 Children died from head injury in the region, the mortality being 5·3 per 100 000 children per year. Head injury was the single most important cause of death in children aged >1 year, accounting for 15% of deaths in children aged 1-15 years and a quarter for those aged 5-15 years. 121 Potentially avoidable factors possibly or probably contributing to death occurred in 81 children (32%). Half the children (125) died before admission, 27 of whom (22%) had potentially avoidable factors possibly or probably contributing to death, and 130 died after admission, 54 of whom (42%) had 93 such factors, which included failure of diagnosis or delayed recognition of intracranial haemorrhage or associated injury, inadequate management of the airways, and poor management of the transfer between hospitals.**

***Implications*—Regions should revise urgently their guidelines for optimal management and indications for neurosurgical referral to include children with severe head injuries and audit their systems of care for all patients with head injuries.**

Introduction

Trauma and particularly head injury are well recognised as the major cause of death in children aged over 1 year.[1,2] The mortality reported from specialist neurosurgical centres after severe head injury in childhood ranges from 6% to 35%.[3-5] Although these widely differing values probably reflect varying patterns of referral rather than different approaches to management,[6] Bruce *et al* suggested that the mortality for children in hospital with severe head injury should not exceed 10%[7] and implied that in centres with a higher mortality factors contributing to the deaths of some children may be avoidable with a more aggressive approach to management.

Previous studies of the management of adults and children with fatal head injuries indicate that up to 30% of those who died have had potentially avoidable secondary complications that probably contributed to death; these complications include delay before evacuation of intracranial haematomas,[8] secondary brain damage caused by hypoxia and hypotension,[9,10] uncontrolled convulsions,[11] and complications of general anaesthesia.[12] Most of the subjects have been adults, with children constituting only a small proportion. Although the probability of secondary complications is different in children compared with adults,[13,14] the incidence of potentially avoidable complications has not been investigated exclusively in children with fatal head injuries.

We therefore undertook a review of deaths in childhood from head injury in the Northern region to determine the mortality from head injury in childhood in a population based rather than a hospital based study and the proportion of fatally injured children in whom potentially avoidable factors were likely to have contributed to death.

TABLE II—*Details of children who died before and after admission*

	Before admission (n=125)	After admission (n=130)
Age		
Median (years)	10	10
Range	6 weeks-15 years	2 weeks-15 years
Median (range) injury severity score[15 16]	34·0 (16·0-75·0)	31·5 (4·0-75·0)
No with injury severity score=75	36	2

Subjects and methods

We identified all children aged under 16 years who had died from head injury in the Northern region during the eight year period 1979-86. Head injury was defined according to the diagnostic codes of the International Classification of Diseases (ninth revision) as N800, fracture of the vault of the skull; N801, fracture of base of skull; N802, fracture of bones affecting the skull or face with other bones; N803, other unqualified skull fractures; N804, multiple fractures affecting the skull or face with other bones; N850, concussion; N851, cerebral laceration or contusion; N852, subarachnoid, subdural, and extradural haemorrhages after injury; N853, other and unspecified intracranial haemorrhage after injury; and N854, intracranial injury of other and unspecified nature.

The children who died were identified from data obtained from the Office of Population Censuses and Surveys and the Hospital Activity Analysis. The hospital case notes, coroners' records, and necropsy reports of all the children who died were studied, the permission of the hospital consultants and coroners having first been obtained. Each child was assigned an injury severity score according to the method of Baker.[15 16] In all children with a score of 75, indicating a necessarily fatal injury, no avoidable factors contributing to death were considered to be present.

If a patient with a head injury talks after their injury and subsequently dies this has been taken by many to indicate that the primary brain injury was not overwhelming and that death resulted from secondary complications or associated injuries.[11 17 18] All such deaths, whether occurring before or after admission to hospital, were therefore classed by us as probably preventable.

Necroscopic evidence of appreciable aspiration of blood or vomit indicating airways obstruction was considered to be a potentially avoidable factor which *possibly* contributed to death.

In children who died after admission to hospital we identified potentially avoidable factors using similar criteria to those of Jeffreys and Jones.[17] In addition to the factors listed above, children were classed as having avoidable factors *probably* contributing to death if the children had an appreciable intracranial haematoma or an appreciable associated injury that was not diagnosed or when treatment was delayed.

Extradural and subdural haematomas were considered to be important when they were thicker than 1 cm; small haematomas associated with depressed fractures of the skull were excluded. If the thickness of the haematoma was not given it was considered to be important if described as large or moderate but not if described as small or thin. For intracranial haematomas a delay of more than two hours between a decline in conscious level and evacuation is associated with poor outcome.[8] Delayed evacuation of a haematoma was thus defined as a delay of more than two hours between the first recorded deterioration in conscious level and evacuation. In a few cases evacuation of a haematoma had been attempted but the necropsy report referred to a large or important residual haematoma; these were included as cases of failed evacuation.

Children who died from associated injuries were classed as having avoidable factors *probably* contributing to death if a life threatening injury was not diagnosed in life and more than two hours had elapsed between admission and death or if the child was transferred to another hospital with a potentially life threatening undiagnosed injury—for example, a ruptured abdominal viscus or a pneumothorax.

The occurrence of systemic hypoxia or hypotension is associated with increased mortality and morbidity after head injury.[19] Children were therefore regarded as having avoidable factors *possibly* contributing to death if they had had an unexpected respiratory arrest after admission. It was not possible to determine the incidence of hypotension as blood pressures were not consistently recorded in the notes.

TABLE I—*Distribution of childhood deaths from head injuries by age and sex*

Age (years)	<1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Male	7	5	5	5	6	15	8	13	8	14	17	9	15	21	11	15
Female	4	5	7	2	1	2	7	2	5	3	10	6	7	9	6	5
Total	11	10	12	7	7	17	15	15	13	17	27	15	22	30	17	20

Results

Over the eight year study period 25 134 children died from or were admitted to hospital with a head injury, representing one admission or death each year for every 200 children in the region. Two hundred and fifty five children died from head injury, a mortality of 5·3 per 100 000 children per year, accounting for 15% of all deaths in children older than 1 year and a quarter of deaths in those older than 5.

Mortality was higher in older children (table I), being 4·2 per 100 000 children per year in the age group 0-4 years, 4·9 per 100 000 in the age group 5-9 years, and 6·8 per 100 000 in the age group 11-15 years.

One hundred and twenty five children (49%) died before admission to hospital and 130 after. Table II summarises details of these two groups. There was no appreciable difference in the age structure of the two groups, and, although the median injury severity scores were similar, 36 (29%) of the children who died before admission had necessarily fatal injuries (severity score 75) compared with only two (1·5%) of those who died after admission. The children who died before admission thus had significantly higher injury severity scores (Mann-Whitney U test; $p=0{\cdot}02$).

DEATHS BEFORE ADMISSION

The 36 children with an injury severity score of 75 and 22 children declared dead at the scene of the accident by a doctor were excluded from subsequent analysis.

CHILDREN WHO TALKED AND DIED

Three of the remaining 67 children talked between injury and death (table II), one of whom aspirated vomit, the other two had no associated injuries, and both had marked cerebral oedema at necropsy but no other apparent cerebral pathology. These three children were all classed as having potentially avoidable factors probably contributing to death.

CHILDREN WHO ASPIRATED

Twenty five of the 67 children had necroscopic evidence of appreciable aspiration of blood or vomit (table III), including one child mentioned above who talked and died. There was no significant relation between the duration of the journey to hospital and incidence of aspiration ($p>0.5$).

These children had significantly lower injury severity scores than the remaining 42 children who died without evidence of aspiration (fig 1) (Mann-Whitney U test; $p<0.05$). This suggests that hypoxia resulting from aspiration may have contributed to death in these 25 children and we therefore classified them as having an avoidable factor possibly contributing to death.

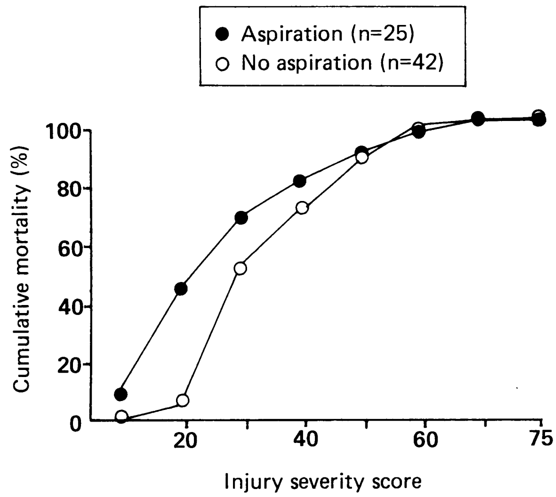

FIG 1—*Cumulative mortality by injury severity score in children with potentially survivable injuries with or without necroscopic evidence of aspiration who died during transfer to hospital*

In total, in 27 (22%) of the 125 children who died before admission were classified as having potentially avoidable factors probably or possibly contributing to death.

DEATHS AFTER ADMISSION

Of 130 children who died after admission, 25 (19%) were admitted directly to one of the two neurosurgical centres that serve the region and 105 (81%) were admitted initially to a district general hospital, of whom 68 were subsequently transferred to one of the two regional neurosurgical centres. Thirty six children died at a district hospital without being transferred, and one child died at home 14 days after discharge. Thus 93 children were admitted to the regional neurosurgical centres in the region, of whom three were subsequently transferred to district general hospitals for terminal care.

CHILDREN WHO TALKED AND DIED

Twenty one children talked after their head injury and subsequently died after admission (table III), of whom 11 had intracranial haematomas, which were either not diagnosed in life or in which treatment was delayed, and seven had respiratory arrests after admission; the remaining three children had cerebral oedema but no other evidence of appreciable brain injury at necropsy.

All these 21 children were classed as having one or more avoidable factors probably contributing to death.

INTRACRANIAL HAEMATOMA

Twenty six children had an intracranial haematoma that was not diagnosed before death or in which treatment was delayed or not effective; two died within four hours after admission, and the remaining 24 were classified as having a potentially preventable factor (table III). Eleven children talked between injury and death, eight had an extradural haematoma, 12 had a subdural haematoma, two extradural and subdural haematomas, three an intracerebral haematoma, and one an intracerebellar haematoma.

In 13 children the haematoma was not diagnosed before death. Two of them died within four hours after admission and were therefore not classified as having a potentially avoidable factor. The remaining 11 children were classified as having an avoidable factor; 10 died in hospital; the median time between injury or deterioration in conscious level and death was 44 hours (range four to 168 hours). One child died at home from a subdural haematoma 14 days after discharge.

In seven children an intracranial haematoma was diagnosed and in six treated, but nevertheless large haematomas were found at necropsy. Three were extradural haematomas and four subdural haematomas. In four children evacuation had been carried out with burr holes and in two infants with needle aspiration through the anterior fontanelle. One further child had a small subdural haematoma diagnosed on computed tomography and was managed conservatively; in the necropsy report the haematoma was described as large. All these children were classified as having a potentially avoidable factor.

Six children had evidence of a delay of more than two hours between the deterioration in their conscious level and evacuation of the haematoma and were classed as having an avoidable factor. Five children had extradural haematomas and one an intracerebellar haematoma; all were initially admitted to a district hospital and subsequently transferred to a regional neurosurgical centre. The median delay between deterioration in conscious level and evacuation was 18 hours, range four to 36 hours. Five children talked between injury and death.

In total, 24 children who died with an intracranial haematoma were classified as having a potentially preventable factor probably contributing to death.

ASSOCIATED INJURY

Thirteen children died with an unrecognised associated injury (table III); six had ruptured spleens, three lacerated livers, two rupture of more than one abdominal viscus, one a ruptured iliac artery, and one a pneumothorax. The associated injury was not diag-

TABLE III—*Summary of avoidable factors possibly or probably contributing to death in children with head injury**

	Before admission		After admission			
	Talked and died	Aspiration and respiratory arrest	Talked and died	Aspiration and respiratory arrest	Associated injury	Intracranial haematoma
No of children	3	25	21	35	13	24
Median age (range) (years)	10 (7-15)	11 (0·5-15)	9 (2-15)	7 (0·1-15)	9 (1-15)	9 (0·1-15)
Median (range) injury severity score	16·0	25·0 (9·0-66·0)	9·0 (4·0-48·0)	25·0 (4·0-59·0)	48 (41·0-59·0)	22·5 (16·0-59·0)

*In some children more than one avoidable factor occurred nosed in life for 12 children in whom the median time from hospital admission to death was five hours (range two to 67 hours). Another child was transferred between hospitals with an undiagnosed ruptured spleen and arrived in a critical condition; despite initial resuscitation she died later.

All 13 children were classified as having a potentially avoidable factor probably contributing to death; two of them also had an undiagnosed intracranial haematoma.

RESPIRATORY ARREST OR AIRWAYS OBSTRUCTION

Thirty one children had an unexpected respiratory arrest requiring emergency intubation and ventilation after admission from the accident and emergency department (table III). Twenty two children had respiratory arrest in the ward, one during a radiological investigation, and eight during transfer from a district hospital to a regional neurosurgical centre. An additional four children had necroscopic evidence of appreciable aspiration of blood or vomit.

To try to determine whether these events had a significant adverse effect on outcome the injury severity scores of these 35 children were compared with those of children who died after admission without an unexpected arrest or evidence of aspiration (fig 2) and were found to be significantly lower (Mann-Whitney U test; $p<0.01$). These data suggest that hypoxia may have contributed to death. We therefore classified these 35 children as having an avoidable factor possibly contributing to death; 19 of the children also had one or more other preventable factors.

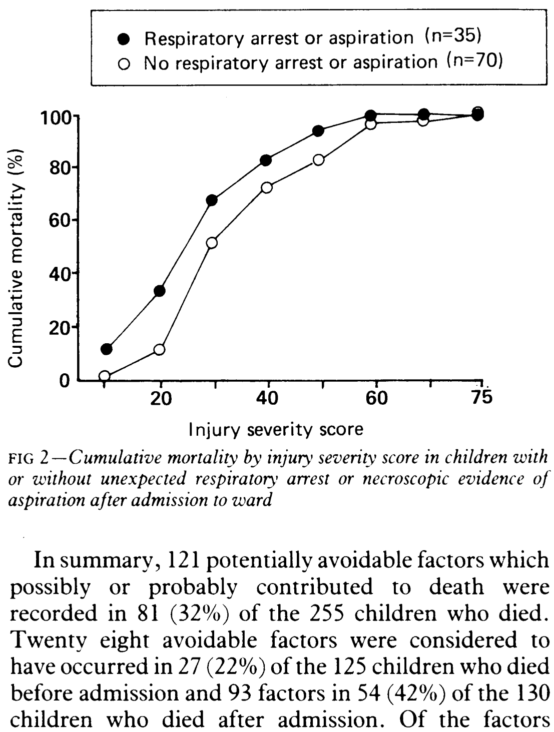

FIG 2—*Cumulative mortality by injury severity score in children with or without unexpected respiratory arrest or necroscopic evidence of aspiration after admission to ward*

In summary, 121 potentially avoidable factors which possibly or probably contributed to death were recorded in 81 (32%) of the 255 children who died. Twenty eight avoidable factors were considered to have occurred in 27 (22%) of the 125 children who died before admission and 93 factors in 54 (42%) of the 130 children who died after admission. Of the factors occurring after admission, 36 occurred at district general hospitals, 11 during transfer from a district hospital to a regional neurosurgical centre, and 46 at a regional neurosurgical centre. For the children who died after admission to hospital the median time between injury and death was 29·5 hours.

Discussion

Head injury was the major single cause of death in childhood in the Northern region during the eight year period of the study. Our survey shows that potentially preventable factors occurred in 22% of the children who died before admission to hospital and in 42% of children who died after admission.

The system for identifying avoidable factors in our study was based on that used by others,[17 20] and the incidence of avoidable factors occurring after admission in our study (42%) is similar to that reported for adults with head injuries (54%)[17] and trauma (33%).[21] This is perhaps surprising in view of the different incidence of secondary complications after head injury in children.[13 14]

There is bound to be some controversy about defining an "avoidable factor" in a retrospective study. We cannot comment on the importance of these factors in contributing to death in individual cases because the necessary data to determine the probability of survival in each child with the TRISS methodology score[22] or a neuropathological weighting system[23] was not obtained during admission or at necropsy. Despite these reservations the data show that the care given to many children with head injuries who died was less than optimal, and similar avoidable events probably also occur in children who survive severe head injury and contribute to morbidity.[20] It is salutary therefore that it is more than 10 years since Jennett first drew attention to the need for improved organisation of the system for managing patients with head injuries[12]; the results of our study and other recent studies[17 21] show that much still needs to be done.

The finding of the Field report, that 60% of deaths from head injury occurred before admission to hospital,[24] led to the suggestion that better care at the scene of an accident and during transfer to hospital might reduce mortality. In a retrospective study of adults who died from trauma before admission to hospital Yates compared the injury severity scores of patients who died with necroscopic evidence of airways obstruction to those of patients who had clear airways.[25] He found no significant difference between the two groups even when subgroups of less severely injured patients were considered and therefore concluded that more advanced training of ambulance drivers in managing the airways probably would not prevent deaths from trauma.

Contrary results were found in our study, although a similar methodology was used. Thus children with potentially survivable injuries died during transfer to hospital with significantly lower injury severity scores if they had aspirated than children with clear airways. In addition, early intubation and ventilation, perhaps combined with the use of intravenous mannitol, might have prevented the deaths of the two children with severe cerebral oedema who talked and died. These results and the findings from two studies in the United States that advanced prehospital care can appreciably reduce mortality[26 27] indicate that this issue deserves prospective evaluation in the United Kingdom.

In our retrospective review 12 children with head injuries died with an undiagnosed major associated injury and in a further child there was considerable delay before diagnosis. These findings support the conclusions of the retrospective study of deaths from trauma by the Royal College of Surgeons[21] and indicate that there is an urgent need to devise ways of improving the initial assessment and management of patients admitted to hospital in the United Kingdom after severe trauma.

Attention has also been drawn to the hazards of inter-hospital transfer of comatose patients with head injury,[28] and guidelines for safe transfer have been published.[29] Despite this, 15 of the 68 children with fatal head injuries who were transferred among hospitals in this study arrived at the referral hospital in a critical condition.

There has been considerable discussion about the advantages and disadvantages of routine intubation and ventilation in managing patients with severe head injury.[30-34] The high incidence of adverse respiratory events in this study and the finding that children in whom such events occurred died with significantly lower injury severity scores leads us to conclude that children with severe head injuries should be routinely intubated and ventilated.

That 26 children died with an undiagnosed or inadequately treated intracranial haematoma is a matter for concern as the principal reason for admitting one child in every 200 in this region each year was to prevent such deaths. Guidelines for the optimal management and indications for neurosurgical referral of patients with head injury were devised and published in 1984,[29] and yet there was no obvious change in the pattern of practice in the two years subsequently. These guidelines, however, were not specific to children and may not be widely disseminated among paediatric departments.

It is unfortunate that the guidelines did not deal with the particular difficulties associated with assessing the level of consciousness of young children with head injury.[35-37] It was evident from the review of the notes that there was often difficulty in assessing consciousness in very young children and a formal assessment of the level of consciousness was only infrequently recorded. These difficulties and the importance of trauma as a cause of death in childhood suggest that children with head injury comprise a group worthy of particular attention. There is an urgent need for regions to revise the guidelines to include recommendations for optimal practice for assessing children with severe head injuries and to conduct ongoing audit of their systems of care for all patients with head injury. Such audit would best be conducted with the TRISS methodology,[22] but this would require establishing local and national databases.

The results of this study may be dismissed as yet another "table top theoretical exercise."[38] We see, however, little merit in devising new methods of treating patients with severe brain injury if they are not already receiving the best care currently available. Head injury is the most common cause of death in childhood, and many of these deaths may be preventable. Paediatricians, neurosurgeons, general surgeons, and accident and emergency consultants should surely take on the task of improving its management without delay.

We thank Action Research for the Crippled Child and the Newcastle District Health Authority's scientific and research committee for their generous support, Mr A McNay and Dr S Jarvis for their advice, and the coroners in the Northern region and their staff and the consultants who cared for the children for their kind co-operation. JAE is a Wellcome senior fellow in clinical science.

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THE MEMOIR CLUB

His [Ashley Miles's] keen sense of humour was an essential part of him—as much indeed as his capacity to see right into the heart of any problem, scientific or personal, with which he was confronted. He knew what to discard as surely and as quickly as he was able to identify what mattered. I well remember once having a bread and cheese lunch with him at Mill Hill while we discussed a scientific problem of common interest. At one point his wife Ellen came in to his room with a set of papers laying out the controls for a crucial experiment then being planned. I was drawn into the discussion. Ashley proceeded to discard one after another of Ellen's proposed controls, at which point Ellen appealed to me for support. I could see the point of the many controls she was proposing. But Ashley had a different angle.

"Let's first see if the target can be hit," he said, "and if it is we'll do it again; next time with every single one of your controls. If the target is not hit we can be spared the pain of setting up all these controls."

"Is *that* a way to do a scientific experiment?" asked Ellen sternly, looking to me for backing. Before I could reply Ashley shot in his final word: "It's a question of just how pure you want to be!"

He got his way, of course, with good humoured laughter at his sally; but it was his way of making the serious scientific point that nothing must be allowed to distract attention from or obscure the real object of an experiment.

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