ORIGINAL ARTICLE

Epidemiology of traumatic brain injury in children receiving intensive care in the UK

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Aims: To describe the epidemiology of children with traumatic brain injury (TBI) admitted to paediatric intensive care units (PICUs) in the UK.
Methods: Prospective collection of clinical and demographic information from paediatric and adult intensive care units in the UK and Eire between February 2001 and August 2003.
Results: The UK prevalence rate for children (0–14 years) admitted to intensive care with TBI between February 2001 and August 2003 was 5.6 per 100 000 population per year (95% Poisson exact confidence intervals 5.17 to 6.05). Children admitted to PICUs with TBI were more deprived than the population as a whole (mean Townsend score for TBI admissions 1.19 *v* 0). The commonest mechanism of injury was a pedestrian accident (36%), most often occurring in children over 10. There was a significant summer peak in admissions in children under 10 years. Time of injury peaked in the late afternoon and early evening, a pattern that remained constant across the days of the week. Injuries involving motor vehicles have the highest mortality rates (23% of vehicle occupants, 12% of pedestrians) compared with cyclists (8%) and falls (3%). In two thirds of admissions (65%) TBI was an isolated injury.
Conclusions: TBI in children requiring intensive care is more common in those from poorer backgrounds who have been involved in accidents as pedestrians. The summer peak in injury occurrence for 0–10 year olds and late afternoon timing give clear targets for community based injury prevention.

Injury is the main cause of death and disability in children worldwide.[1] In 2002, traumatic brain injury (TBI) caused 2% of all deaths in those aged 0–14 years, 6% of all deaths, and 30% of deaths due to external causes of injury in 1–14 year olds in England and Wales.[2 3] This represents a marked improvement in mortality since Sharples and colleagues noted that TBI accounted for 15% of all deaths in the 1–15 year age group in northern England.[4] There is, however a concomitant increase in stress and effects on health of parents of children surviving TBI as well as a greater financial burden on their families.[5] This increased level of stress may be exacerbated in families with lower socioeconomic status whose children have sustained a TBI as, in the 6–12 year age group, they exhibit poorer social functioning.[6]

In this study we describe the epidemiology of children admitted with TBI to intensive care to provide baseline information on age and sex distribution, prevalence, socio-economic status, severity and mechanism of injury, time and day of injury, seasonality, and mortality.

METHODS

Clinical data

Anonymised demographic and clinical data on all children admitted with TBI to 28 paediatric intensive care units (PICUs) in England, Wales, Scotland, Northern Ireland, and Eire were collected by clinicians or PICU nurses between February 2001 and August 2003 (depending on commencement date), with each unit collecting data over at least a period of one year. The inclusion criterion for this study was a diagnosis of TBI as the primary reason for admission to PICU identified in the clinical notes.

Data were entered onto two pre-printed forms: one covered demographics, admission information including injury severity, and care in the first 24 hours after admission; the other, subsequent hospital care until discharge. Data items used for this study were date of birth, sex, postcode of home address, admission date and time, cause of injury, Glasgow Coma Scale (GCS)[7] at presentation to an accident and emergency department, other injuries of sufficient severity to warrant hospital admission, and mortality. The data collection forms were returned to a single centre for data input onto a central database and subject to logical and analytical data validation checks.

Anonymised data on children under 16 years admitted with TBI as the primary reason for admission to 48 adult ICUs were obtained from the Intensive Care National Audit Research Centre (ICNARC) for the period 1 April 2001 to 31 March 2002. A crosscheck between these two datasets identified children who were transferred from an adult ICU to a PICU to avoid double counting.

Ethical approval for this study was obtained from the West Midlands Multicentre Research Ethics Committee (MREC/01/7/27). Approval was also gained from local research ethics committees for each participating PICU.

Population data

Population counts from the 2001 Census were obtained for Northern Ireland,[8] Scotland,[9] and England and Wales[10] as were the data required to calculate the Townsend score.[11]

Data sources, completeness, and ascertainment

In total, 721 admissions were identified across the data collection period. These included 501 for whom a fully or partially completed data collection form was returned. For 110 admissions, limited data including age, date of admission, and outcome were obtained. Count data (confirmation of numbers only) were obtained for 22 admissions.

Abbreviations: ICU, intensive care unit; PICU, paediatric intensive care unit; TBI, traumatic brain injury

Table 1 Demographic characteristics

Area	Male	Female	NK	Total no.*	Median age	IQR Lower	IQR Upper
UK and Eire	415	205	24	644	8.8	4.1	12.1
England and Wales	357	180	19	556	8.8	4.0	12.2
Scotland	33	10	0	43	9.8	6.3	12.0
Northern Ireland	14	8	5	27	6.9	3.6	12.3
Eire	11	7	0	18	9.8	6.8	11.5

*Includes all data for children aged 0–14 years admitted to paediatric and adult ICUs with TBI for whom details were made available. The total number is higher than used for calculating annual prevalence as some units collected more data over a period greater than one year.
NK, not known; IQR, interquartile range.

Anonymised data on 125 children admitted to adult ICUs were obtained from ICNARC. Eighty five of these (12% of the full dataset) had not been subsequently transferred to a PICU and their details were added to the dataset. A further three admissions from an adult unit not contributing to ICNARC were also included. Demographic data, excluding those for whom age at admission was imputed, were available for 644 children. For 23 children, age category was imputed based on the age distribution of those for whom data were available.

Ascertainment of the case series was carried out by systematic telephone follow up of each PICU by the study lead investigator (KM). In addition, non-participating PICUs and adult ICUs not returning data to ICNARC were approached in a telephone census to ascertain numbers of any additional paediatric admissions for TBI.

Analytical methods

Age specific and age standardised prevalence rates for children aged 0–14 admitted with TBI for intensive care in the UK were calculated using 2001 Census populations with Poisson exact 95% confidence intervals based on the 623 admissions that constituted the admissions for one year for each unit over the study period. Rates were not calculated for Eire as no details on admissions to Irish adult ICUs were available. Seasonality of admissions numbers overall and by age group was formally tested with Edwards' test using an exact method that allows for different day length of months.[12] Other comparisons were carried out using χ^2, *t* test, Mann-Whitney U test, and Kruskall-Wallis test. All analyses were carried out in Stata version 8.[13]

RESULTS

Demographic information on 644 children aged 0–14 years admitted to paediatric and adult ICUs are detailed in table 1. The median number of TBI admissions to PICUs over one year in the UK was 22 (IQR 9–36). Children admitted to adult ICUs and not transferred to a PICU ($n = 85$) were significantly older than children admitted to PICUs (adult ICU median age in months: 155, IQR 105–171; PICU median age in months: 108, IQR 50.5–149), two sample Wilcoxon rank sum (Mann-Whitney) test: $z = -5.290$, $p < 0.0001$). The 40 children initially admitted to an adult ICU and subsequently transferred to a PICU were approximately 3 years younger.

Prevalence rates for admission with TBI in the UK are presented in table 2. Although not statistically different, rates range between 5.6.per 100 000 per year in England and Wales to 7.3 per 100 000 per year in Northern Ireland. The pattern of rates by age group is also not consistent between the countries, with a significantly smaller number of 0–4 year olds admitted in Scotland (2.5 per 100 000 per year, 95% CI 0.66 to 4.40) compared with England and Wales (5.3 per 100 000 per year, 95% CI 4.48 to 6.11).

Children admitted to PICUs in England, Wales, and Scotland came from significantly less affluent areas compared to the whole population (mean Townsend score for TBI admissions 1.19 *v* 0 for the whole population, $t = -7.55$, $p < 0.0001$). Lower (including negative) Townsend scores represent higher socioeconomic status, higher values represent lower socioeconomic status. Figure 1 illustrates the comparative distributions of Townsend score for the two groups.

Table 2 Prevalence rates for 0–14 year old children admitted with TBI to PICUs and ICUs in England, Wales, Scotland, and Northern Ireland*

Area	Age group (y)†	No.	Population (2001 census)	Rate (10^5 y^{-1})	95% CI Lower	95% CI Upper
UK	0–4	179	3486469	5.1	4.38	5.89
	5–9	178	3738160	4.8	4.06	5.46
	10–14	266	3880609	6.9	6.03	7.68
	0–14	623	11105238	5.6	5.17	6.05
England and Wales	0–4	164	3094357	5.3	4.48	6.11
	5–9	153	3307972	4.6	3.89	5.36
	10–14	234	3425075	6.8	5.95	7.71
	0–14	551	9827404	5.6	5.14	6.08
Scotland	0–4	7	276874	2.5	0.66	4.40
	5–9	18	307138	5.9	3.15	8.57
	10–14	20	322870	6.2	3.48	8.91
	0–14	45	906882	5.0	3.51	6.41
Northern Ireland	0–4	9	115238	7.8	2.71	12.91
	5–9	7	123050	5.7	1.47	9.90
	10–14	11	132664	8.3	3.39	13.19
	0–14	27	370952	7.3	4.53	10.02

*Data based on admissions between 1 February 2001 and 31 August 2003, taking a single calendar year for each PICU/ICU.
†For 23 children, age category was imputed based on the age distribution of those for whom data was available.

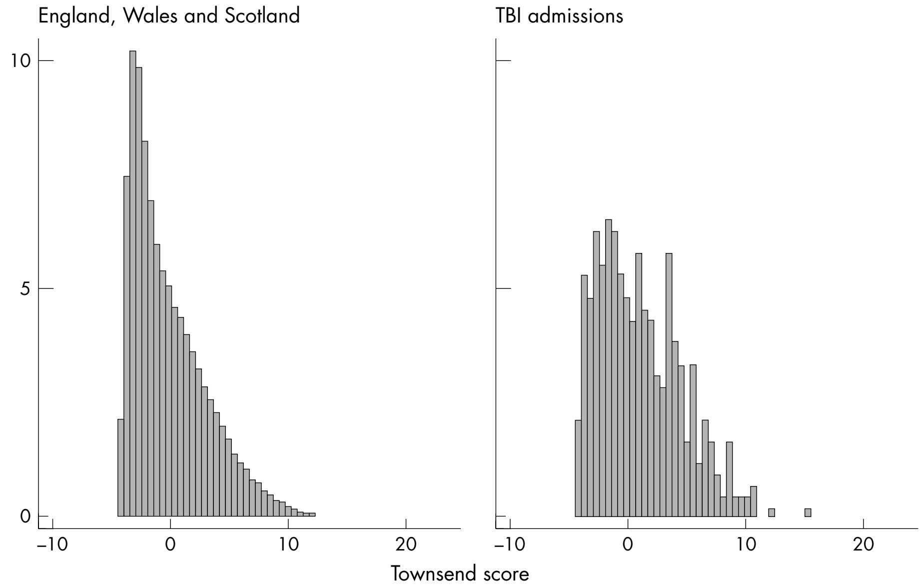

Figure 1 Comparison of Townsend score between general population of England, Wales, and Scotland and children admitted with TBI to PICUs (2001 Census). Based on 419 admissions for whom a valid home address postcode was available.

A significant seasonal summer peak was observed for 0–4 year olds and 5–9 year olds (χ^2 (2 df) 8.8, p = 0.01 and χ^2 (2df) 15.4, p = 0.0005, respectively), but was less marked in the 10–14 year olds (χ^2 (2df) 5.5, p = 0.06). Figure 2 plots the number of admissions by age group against month of admission, together with the expected number of admissions in each month fitted to a simple harmonic curve.[12] Although admission numbers were slightly raised on Fridays and Saturdays, there was no significant difference between individual days of the week. Similarly, time of admission did not vary significantly between weekdays (Monday to Friday) and weekends (Saturday and Sunday). Time of injury showed a peak around mid-to-late afternoon with very few injuries occurring between midnight and 0600 hours (fig 3).

Table 3 details numbers of children by mechanism of injury and age group. Table 4 presents numbers of children by GCS score (recorded at accident and emergency departments) and mortality by mechanism of injury. The predominant cause of injury was accidents involving pedestrians and these formed the largest group (36% of all admissions) and represented 57% of all admissions with a severe GCS score (3–8). A comparison of GCS scores across the four main injury mechanisms (pedestrians, motor vehicle occupants, cyclists, and falls) indicates that they are significantly different

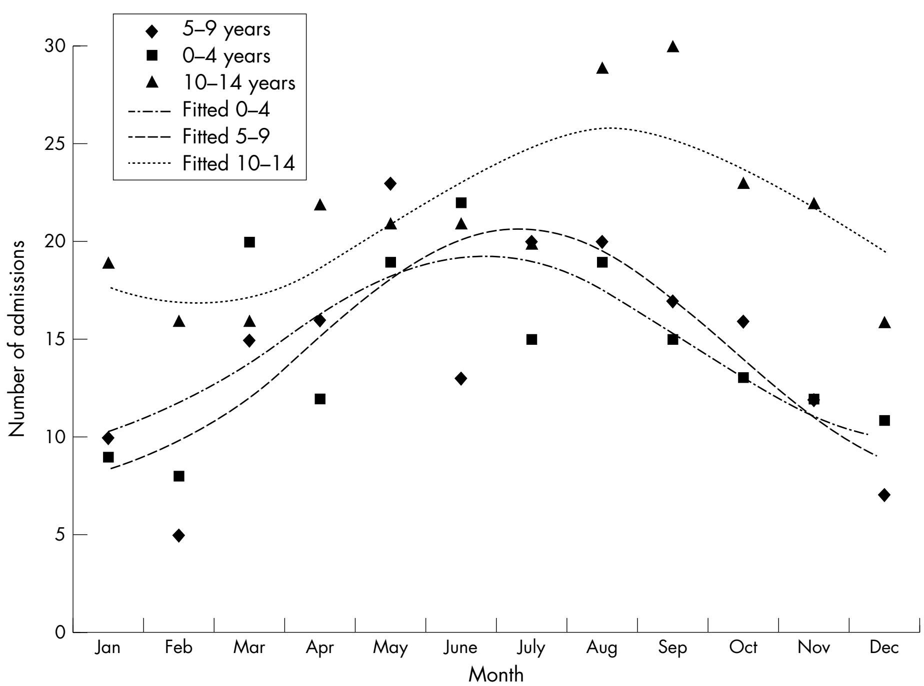

Figure 2 Seasonality of admissions by age group 2001–03. Data based on admissions between 1 February 2001 and 31 August 2003 and excluding 20 children for whom an admission month was not available.

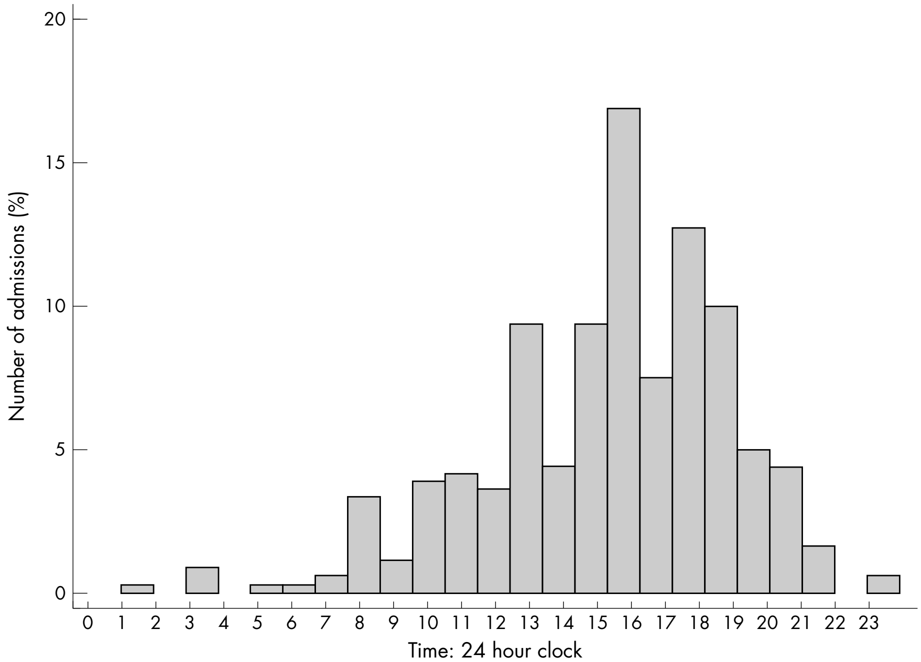

Figure 3 Time of injury (supplied for 362 admissions).

(Kruskal-Wallis test: χ^2 (3df), 11.9, $p = 0.008$). Mortality varied considerably with mechanism of injury, from 23% for motor vehicle occupants, 12% for pedestrian accidents, to 3% for falls. It is clear that the mechanism of injury varies with age: over half of those aged under 1 year were admitted for suspected assault (non-accidental injury); in the 1–4 year age group, falls are the main cause of injury, but this changes to pedestrian accidents in the 5–15 year-olds.

The most common associated injuries were limb (21%), facial (12%), chest (9%), and abdomen (5%). The presence of associated chest, abdominal, or pelvic injury was associated with increased mortality (20% *v* 7.3% for those with no associated injury, χ^2 (1df), 10.8; $p = 0.005$).

DISCUSSION

This study has collected data on a subset of all children suffering from TBI in the UK who required admission to intensive care and provides baseline information necessary for the planning of public health intervention and healthcare delivery, including demographics, annual and seasonal admission rates, timing, and cause and severity of injury.

The prevalence rates calculated for children admitted to intensive care with TBI are based on a one year rolling period between February 2001 and August 2003. Based on these rates, PICUs in the UK can expect to admit between 570 and 670 children per year. With no suitable independent sources of ascertainment available, it is possible that we have missed some admissions and acknowledge that overall prevalence of TBI may be slightly higher. It is also difficult to compare these rates with other studies as inclusion criteria, age ranges, and definitions of TBI vary widely between studies.[14 15] For example, Baldo *et al* describe hospitalisation rates for severe TBI in Italy at approximately 17 per 100 000 for all ages between 1996 and 1999.[16] In Sweden, only 1.5% of accident and emergency attendances (for all ages) had a loss of consciousness of greater than 30 minutes corresponding to about 8 per 100 000.[17]

The criterion for inclusion in this study was a diagnosis of TBI recorded as primary reason for admission; however, it is conceivable that some with minor or moderate TBI were admitted to PICU in view of an associated injury, which was present in just over a third of cases. This study aimed to capture information on all children admitted to intensive care with a primary diagnosis of TBI at all levels of injury severity, but did not include the small number of children admitted to intensive care with extra-cranial injuries without evidence of TBI. Children who died at the scene, in accident and emergency or in other healthcare areas are not included. The large number of children admitted to the PICU with a

Table 3 Mechanism of injury by age group

	Age group (years)*											
Injury mechanism	<1	(%)	1–4	(%)	5–9	(%)	10–14	(%)	15+	(%)	Total	(%)†
Pedestrian	1	(3)	26	(25)	60	(40)	82	(43)	12	(44)	181	(36)
Fall	6	(19)	46	(44)	31	(21)	31	(16)	4	(15)	118	(24)
Cyclist	0	(0)	2	(2)	17	(11)	28	(15)	5	(19)	52	(10)
Motor vehicle occupant	4	(13)	10	(9)	17	(11)	14	(7)	2	(7)	47	(9)
Other	2	(6)	3	(4)	13	(9)	21	(11)	0	(0)	40	(8)
Suspected assault	16	(52)	6	(6)	0	(0)	3	(2)	3	(11)	28	(6)
Unknown	2	(7)	11	(10)	11	(7)	10	(5)	1	(4)	35	(7)
Total	31	(6)	105	(21)	149	(30)	189	(38)	27	(5)	501	

*Row percentages.
†Column percentages.

Table 4 Mechanism of injury and mortality by Glasgow Coma Scale at accident and emergency department

	Glasgow Coma Scale at A&E*											Deaths	
Injury mechanism	3–8	(%)	9–12	(%)	13–15	(%)	NR	(%)	NV	(%)	Total	No.	(%)
Pedestrian	76	(42)	35	(19)	32	(18)	8	(4)	30	(18)	181	21	(12)
Fall	18	(15)	25	(21)	30	(25)	10	(9)	35	(30)	118	3	(3)
Cyclist	17	(33)	7	(14)	12	(23)	4	(8)	12	(23)	52	4	(8)
Motor vehicle occupant	10	(21)	9	(19)	9	(19)	8	(17)	11	(23)	47	11	(23)
Other	6	(15)	5	(13)	10	(25)	9	(22)	10	(25)	40	5	(13)
Suspected assault	7	(25)	2	(7)	6	(21)	8	(29)	5	(18)	28	1	(4)
Unknown	0	(0)	0	(0)	0	(0)	33	(94)	2	(6)	35	1	(3)
Total	134	(27)	83	(16)	99	(20)	80	(16)	105	(21)	501	46	(9.2)

*Row percentages.
NR, not recorded; NV, not valid because the child was noted as either intubated, sedated, paralysed, or had suspected seizures.

GCS score of 13–15 at presentation to an accident and emergency (A&E) department initially raises the question of indications for admission to a PICU. A high GCS score at presentation to A&E does not, however, mean that the child is not in need of neuro-intensive care: of 49 children for whom GCS scores were available, 32 (65%) had a subsequent lower score on admission to PICU (14 with a GCS of 8 or less), indicating possible late sequelae from the initial injury. Children are also sometimes intubated prior to transfer to a regional centre or to carry out a CT scan. In some centres, the PICU also functions as a high dependency unit caring for children with less severe injuries.

The socioeconomic differential between the population of children admitted to intensive care due to TBI and the rest of the population reflects earlier data on the relation between poverty and mortality,[18] childhood fractures in Scotland,[19] and childhood injuries in Trent, especially for pedestrians,[20] a large proportion of which, as this study indicates, present with TBI. Interventions in these areas, such as traffic calming[21 22] and promoting cycle helmet use,[23] have the potential for reducing the risk of TBI.

In contrast to adult practice, severe TBI is more commonly an isolated injury in children and may reflect a different mechanism of injury profile. Where polytrauma is present, mortality is significantly higher. Over half of those children under 1 year of age were admitted for suspected assault; however, in this study, this group of children did not have an increased risk of death.

What is already known on this topic

- TBI is a major cause of mortality and morbidity in children in the UK
- Children living in deprived areas are more likely to sustain severe TBI

What this study adds

- Not all children admitted to intensive care with TBI have low GCS scores on presentation to accident and emergency departments
- There is seasonal and daytime variation in occurrence of TBI. Mortality and the proportion of those with a low GCS score vary by mechanism of injury, although these factors do not appear to be linked

The seasonal peak in prevalence of TBI was not observed in fatal head injury accidents in northern England,[4] or by Kraus and colleagues in the USA, although they did observe higher than expected injuries in April, July, August, and September.[24] This peak has been previously noted by Hawley and colleagues.[25] This study indicates that this seasonality is most marked in the 0–10 year old age range. The peak time of injury around mid-to-late afternoon reflects earlier findings[4 24 26] and means that a larger proportion of these children will be admitted to intensive care or for neurosurgery outside normal working hours, a fact that must be accounted for in planning service provision.

The data presented here form part of a much larger dataset including clinical information on monitoring, intervention, and management and detailed outcome information collected one year post-injury. Together, these data form a comprehensive body of knowledge on the epidemiological and clinical characteristics of children with TBI admitted to intensive care, their treatment, and final outcomes.

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