Trends in admission and death rates due to paediatric head injury in England, 2000-2011

Robin Marlow[1,2], Hazel Taylor[3], Julie Mytton[4], Ian K Maconochie[5], Mark D Lyttle[1,3]

[1] Bristol Royal Hospital for Children, University Hospitals Bristol NHS Foundation Trust, Bristol, UK
[2]School of Clinical Sciences, University of Bristol, UK
[3] Research and Innovation, University Hospitals Bristol NHS Foundation Trust.
[4]Centre for Child and Adolescent Health, Faculty of Health and Applied Sciences, University of the West of England, Bristol, UK
[5] Emergency Department, St Mary's Hospital, Imperial College NHS Healthcare Trust, London, UK

Corresponding author:
Dr Robin Marlow
Paediatric Emergency Department, Bristol Royal Hospital for Children, Upper Mauldin Street, BS2 8BJ
robin.marlow@bristol.ac.uk
0117 3428187

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Abstract

Background

The number of children admitted to hospital is increasing year on year, with very short stay admissions doubling in the last decade. Childhood head injury accounts for half a million Emergency Department attendances in the UK every year. The National Institute for Health and Care Excellence has issued three iterations of evidence-based national guidance for head injury since 2003.

Objectives

To assess if any changes in the rates of admission, death, or causes of head injury could be temporally associated with the introduction of sequential national guidelines by longitudinal analysis of the epidemiology of paediatric head injury admissions in England from 1st January 2000 to 31st December 2011.

Methods

Retrospective analysis of English Hospital Episode Statistics data of children under 16 years admitted to hospital with the discharge diagnosis of head injury.

Results

The number of hospital admissions with paediatric head injury in England rose by 10% from 34150 in 2000 to 37430 in 2011, with the proportion admitted for less than one day rising from 38% to 57%. The main cause of head injury was falls (42-47%). Deaths due to head injury decreased by 52% from 76 in 2000 to 40 in 2011. Road traffic accidents were the main cause of death in the year 2000 (67%) but fell to 40% by 2011. In 2000, children who were admitted or died from head injuries were more than twice as likely to come from the most deprived compared to least deprived homes. By 2011 the disparity for risk of admission had narrowed but no change was seen for risk of death.

Conclusions

Significant temporal relationships exist between implementation of the NICE2007 guidance and increased admissions, shorter hospital stay and reduced mortality. The underlying cause of this association is likely tobe multi-factorial.

INTRODUCTION

Over the last decade there has been an increase in childhood hospital admission rates in England, with a pronounced rise in very short stay (less than one day) admissions for medical illnesses.[1] The causes are not clear; re-organisation of primary care out-of-hours provision, introduction of emergency department (ED) waiting time targets and changes in health seeking behaviour have all been suggested.[2] Head injury is the commonest presentation of major and moderate paediatric trauma.[3] Although most have no long term consequences, a proportion suffer traumatic brain injury (TBI),[4] which remains (?) the leading potentially avoidable cause of death and chronic neuro-disability in childhood.[5]

Prompt identification and early intervention in serious TBI may prevent life-changing detrimental outcomes. To detect such injuries cranial Computed Tomography (CT) is the gold standard investigation. It identifies those who require neurosurgical intervention or other intensive therapy, and aids in discharge decisions when normal. With technological advancement and increased availability, rates of CT for childhood head injuries approached 50% in North America by 2003.[6] However the recognition that radiation exposure from CT in childhood may reduce IQ[7] or increase the risk of later malignancy[8,9] has driven research to identify which children are at sufficiently high risk of traumatic brain injury to warrant CT.[4,6,10]

The National Institute for Health and Care Excellence (NICE) has produced three iterations of evidence-based guidelines for the early management of children with head injury in 2003, 2007 and 2014,[11–13] replacing advice from the Royal College of Surgeons (in 1984 and 1999).[14,15] A crucial component in all versions has been guidance regarding imaging. The first NICE guideline was largely extrapolated from adult studies due to limited paediatric-specific evidence. Many clinicians felt this led to unacceptably high CT rates and used locally derived guidelines with higher thresholds and lower scan rates.[16,17] The 2007 revision incorporated criteria from a paediatric UK study;[4] with acceptable CT rates this became widely used, though with some centres making minor modifications.[18] The most recent version (NICE 2014) introduced risk stratification, defining a cohort of children who may be actively observed rather

than progressing to immediate CT scan. This practice for selected patients has been shown to be associated with approximately half the adjusted odds of performing CT and no increase in adverse effects, leading to the suggestion that this approach could safely reduce CT rates.[19]

We aimed to determine whether mortality or admission rates from childhood head injury have changed with successive iterations of NICE guidance, and to explore the epidemiology to identify any potentially alternative influences.

METHODS

Data sources

Hospital Episode Statistics (HES) is a centrally collected anonymised record of all admissions to English National Health Service hospitals. It uses nationally standardized coding systems to record diagnoses (International Classification of Diseases - ICD10), procedures and operations (Office of Population Censuses and Surveys - OPCS4). We used this dataset to identify all admissions during 1st January 2000-31st December 2011 of children under 16 years at the time of admission given a coded diagnosis of head injury (ICD10 codes S00-S09). We grouped the coded mechanism of injury into Road Traffic Injuries (V00-V99), Falls (W00-W19), Struck by animate object (W20-W49), Struck by inanimate object (W50-64), Assault (X85-Y09); Unrecorded and Others (all other coded causes of injury). We identified episodes with neurosurgical interventions (OPCS4 codes A05, A40, A41, V03) or cranial imaging (OPCS4 code U051) although CTs were not routinely recorded before 2006.

We used Office for National Statistics mid-year estimates of the English population as our denominator. To evaluate association of socio-economic status with risk of avoidable injury, we identified the index of multiple deprivation (IMD) decile for the household location of each head injury admission. The IMD provides a relative measure of deprivation at small area level across England. Combining seven different dimensions of deprivation, it ranks England into 32,482 areas from least to most deprived[20].

Data analysis.

To standardize between years, annual head injury admission, mortality, and neurosurgery rates were calculated for the English population under the age of 16 as incidence rate ratios with 95% confidence intervals, relative to the year 2000. For these outcomes a negative binomial regression model was fitted and a test for a linear trend by year was carried out. We assessed guideline eras by assessing the last three years of their use to allow for implementation delays. Between these periods, admission rates, death rates and neurosurgery rates were compared by fitting a negative binomial regression model. Logistic regression models were fitted in order to test for a linear trend by year for the proportion of admissions being admitted for less than a day, one day, or two days or more. To analyse the effects of socio-economic status, we fitted negative binomial models for admission and for death rates over the twelve year period against IMD quintiles (using the least deprived as baseline) adjusting for quintile population density to calculate incidence rate ratios. Data extraction and analysis were completed using the statistical languages R[21] and Stata[22].

RESULTS

[Table 1 – Description of admissions and deaths due to head injury in children aged 0-15 years, 2000-2011]

Epidemiological Trends

Between 2000 and 2011 there was a statistically significant rise in admissions with head injury (Table 1) from 34 to 37 per 10,000 children, whilst the number dying due to head injury fell significantly from 7.6 to 4.0 per million). There was no statistically significant trend in the neurosurgery rate (relative to the population) ($p=0.220$). Of those admitted, the number admitted for a very short duration (less than 1 day) rose 20% from 37.6% in 2000 to 57.4% in 2011 ($p<0.001$ for linear trend). Correspondingly admissions for one day fell by 14% and for two days or more (≥2) dropped by 6% (both $p<0.001$ for a linear trend by year). Between 2006 and 2009 the proportion of admitted patients having a CT rose and plateaued thereafter.

Guideline Eras

[Table 2 – Comparisons between guideline eras].

There was a statistically significant difference in admission rates between guideline eras (p = 0.0022). Admission rates were higher in NICE 2003 compared to RCS. Admission rates were also higher in NICE 2007 compared to either NICE 2003 or RCS. There was a statistically significant difference in death rates between guideline eras (p=0.006), with the death rates statistically significantly lower in NICE 2007 compared to either RCS or NICE 2003. Neurosurgery rates did not differ between guideline eras greater than could have occurred by chance (p=0.1647). For those admitted, the proportion of less than one day admissions rose significantly (p<0.001) between the guideline periods, and the proportion of longer admissions (1 day or 2 days or more) dropped significantly (p<0.001).

Aetiology of admissions and deaths

Figure 1) Causes of head injury admission / year

Figure 2) Causes of head injury death / year

The leading cause of head injuries requiring admission was falls (42-47%) with other causes remaining constant (fig 1). The predominant cause of death (fig2) was road traffic accidents, reducing from 67% of all head injury related deaths in 2000 to 40% in 2011 (p=0.01). Of fatal road traffic accidents, 65-100% were pedestrians or cyclists.

Deprivation

Differences in admission and death rates exist between children from different socioeconomic quintiles. One percent of records were missing socio-economic data, and were excluded from the analysis. In 2000 twice as many children from the most deprived quintiles were admitted (incidence rate ratio [IRR] 2.06 [95% CI 1.99-2.13]) and more than twice as many died (2.31 [95% CI 1.77- 3.02]) compared to those from the least deprived quintile?. Less marked although still significant differences were seen comparing other quintiles [table 3 & 4 online only]. Over the period studied the disparity in rates of admissions

significantly reduced ($p<0.001$) across all levels of socioeconomic status. By 2011 when compared to the highest quintile, the IRR of admission in the lowest quintile had fallen to 1.47[95% CI 1.43-1.52]. With comparatively small numbers of deaths there was no statistically significant interaction between year and deprivation quintile, suggesting that the relationship between death rates and deprivation quintile remained similar across the years.

DISCUSSION

Between 2000 and 2011 rates of admission for childhood head injury rose. However within this overall rise, we have demonstrated an increasing proportion of admissions lasting less than one day, and a significant reduction in the overall number of bed days occupied. Over the same period there was a reduction in mortality due to head injury, whilst the number of children requiring neurosurgical intervention remained constant.

Previous analysis of HES data[23] demonstrated that after introduction of the NICE 2003 guideline, admission rates for adults increased but children were unaffected. We have shown that following implementation of the NICE 2007 guideline there was a statistically significant rise in the number of admissions and fall in the number of deaths in the paediatric population. The clinical decision rule on which NICE 2007 was based predicted a rise in rates of CT scanning from a baseline of 3.3% to just over 14% if fully implemented. It would be expected that full implementation of NICE 2007 guidance would have resulted in increased CT rates, perhaps with an associated reduction in admissions and length of stay. CT scanning and discharge direct from ED compared to admission for observation is a cost-saving strategy. Using the NHS 2013 reference payment tariffs,[24] an ED attendance where the patient has a CT scan and is discharged (VB03Z £242) costs one third the combined tariffs of an ED attendance and admission for observation (£730 = VB04Z £228 + PR07B £502). If clinicians observe children for a short

period of time prior to a decision on the need for imaging (the approach now suggested in NICE 2014) we may see yet further increasing admission rates and resulting costs.

The limitations of our study are mainly due to the nature of the routinely collected dataset. Our choice of outcomes as "admission or death due to head injury" are pragmatic; we were not able to assess how many children survived but had adverse neurological outcomes. Despite HES data being rigorously collected using a strictly defined dataset, it is prone to external factors that may change over time. This can be seen in the anomalous rise in numbers of CT scans following their introduction to the dataset in 2006. HES is the gold standard NHS activity dataset, extracted directly from hospitals' reports to their commissioners to claim payment; and estimated to capture 99.8% of all admissions[25]. It has been postulated that introduction of ED quality indicators (especially the drive to spend no more than four hours in an ED, first introduced in 2001) has caused the rising number of short term admissions. However admission rates for children with medical complaints were already rising[2] prior to their introduction. Neurosurgery rates have not significantly changed despite increasing admissions, suggesting that the overall incidence of severe head injury in childhood has remained relatively constant. We believe that these findings may therefore represent a change in clinician behaviour, with lower severity thresholds for admission combined with shorter stays before discharge. An alternative hypothesis is that the *proportion* of children being admitted has remained constant, but more children are being taken to ED and so more are being admitted. HES data did not include information on ED attendances until 2007 and we have therefore not been able to examine this further.

Our rates of inpatient mortality due to head injury combined with those for Wales over the same time period (personal communication - NHS Wales Infomatics Service) closely approximate the Office for National Statistics figures for total childhood deaths due to head injury in England and Wales.[26] This suggests that most children who die from head injuries do so in hospital rather than at the scene of the incident. The reduction in deaths due to road traffic accidents is likely to be due to a combination of factors. Over this period there have been improvements in safety for car occupants (e.g. use of booster

seats, airbags). However, as the greatest reduction in road traffic deaths has been in pedestrians/cyclists, it may be that the focus on hard hitting road safety campaigns has been beneficial, or that this reflects a reduction in exposure to risk with less walking and cycling in children.

Although there has been improvement over time, the effects of deprivation are still alarming with children dying of head injuries twice as likely to come from the most deprived neighbourhoods. The recent RCPCH report "Why do Children Die"[5] identified injuries and social inequality as two of the modifiable targets to improve the health of children in the UK.

CONCLUSION

These data provide an important snapshot of healthcare use for the commonest childhood injury with significant change in outcomes and resource use over time. Admission rates have changed since the introduction of national guidelines with more frequent, shorter admissions for the same rate of neurosurgical events, indicating that admission rates may not provide a consistent proxy for severity of injury. They also provide a useful measure against which to compare the effects of the NICE 2014 head injury guidance and benchmark any future changes of emergency care provision.

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ONS: Adapted from data from the Office for National Statistics licensed under the Open Government Licence v.1.0.

What is already known on this topic

- Rates of attendances to Emergency Departments with minor medical problems have been steadily rising.
- Head injury is the commonest presentation of moderate and major paediatric trauma

What this study adds

- Between 2000 and 2011, the number of children admitted with head injuries rose significantly and mortality halved.
- These changes can be correlated with the introduction of NICE 2007 guidance although may represent longitudinal shift due to other factors.
- Falls were the predominant cause of admission but road traffic accidents the main cause of death

COMPETING INTERESTS

none

AUTHOR CONTRIBUTIONS

RM conceived the study, obtained the data, undertook the analyses and wrote the first draft of the manuscript. All authors critically reviewed and edited the manuscript.

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306 Table 1 – Description of admissions and deaths due to head injury in children aged 0-15 years, 2000-2011

Guideline	RCS[15]			NICE 2003				NICE 2007				
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Number of HI Admissions	34150	34754	32704	33842	34291	35002	34844	33248	33331	35679	36360	37430
Incidence rate ratio of admission compared to 2000 (95% CI)	1.00	1.03 (1.01-1.04)	0.97 (0.95-0.98)	1.00 (0.99-1.02)	1.02 (1.01-1.04)	1.04 (1.03-1.06)	1.04 (1.02-1.05)	0.99 (0.98-1.01)	0.99 (0.97-1.00)	1.05 (1.04-1.07)	1.07 (1.05-1.08)	1.09 (1.08-1.11)
Number of HI deaths	76	63	59	62	60	42	59	35	35	30	26	40
Incidence rate ratio of death compared to 2000 (95% CI)	1.00	0.83 (0.60-1.17)	0.79 (0.56-1.10)	0.83 (0.59-1.16)	0.80 (0.57-1.13)	0.56 (0.39-0.82)	0.79 (0.56-1.11)	0.47 (0.31-0.70)	0.47 (0.31-0.70)	0.40 (0.26-0.61)	0.34 (0.22-0.54)	0.52 (0.36-0.77)
Number of neurosurgeries	147	127	107	144	127	153	143	116	119	134	117	119
Incidence rate ratio of neurosurgery compared to 2000 (95% CI)	1.00	0.87 (0.69-1.10)	0.74 (0.57-0.94)	0.99 (0.79-1.25)	0.88 (0.69-1.11)	1.06 (0.84-1.33)	0.99 (0.79-1.25)	0.80 (0.63-1.02)	0.82 (0.64-1.04)	0.92 (0.73-1.16)	0.80 (0.63-1.02)	0.81 (0.63-1.03)
% admissions having a CT scan	-	-	-	-	-	-	*6.2	*12.0	14.5	16.4	16.3	16.1
% admissions with length of stay <1 day	37.6	39.6	40.8	41.9	44.7	47.4	50.0	51.2	53.5	55.0	56.4	57.4
% admissions with length of stay =1 day	47.9	46.5	45.1	45.1	43.6	41	39.2	38.1	36.5	35.1	34	33.8
% admissions with length of stay ≥2 days	14.4	13.9	14.1	13.1	11.7	11.5	10.8	10.7	9.9	9.9	9.6	8.8

307 * CT data was not routinely collected prior to 2006, data for 2006 and 2007 may be incomplete

308

309 Table 2 – Comparisons between guideline eras*.

Guideline	RCS	NICE 2003	NICE 2007
Period averaged over	2000-2002*	2004-2006*	2009-2011*
Mean number of admissions per year <16yrs	33668	34891	36105
IRR for the admission rate (95% CI)	1.00	1.04 (1.01-1.06)	1.07 (1.04-1.10)
Mean number of deaths <16 years	66	54	32
IRR for the death rate (95% CI)	1.00	0.82 (0.67-1.01)	0.48 (0.38-0.62)
Mean number of admissions with neurosurgery per year	126	142	122
IRR for the neurosurgery rates (95% CI)	1.00	1.12 (0.97-1.30)	0.97 (0.83-1.12)
Proportion of admissions with a length of stay of <1 day	39.3%	47.4%	56.3%

310 *comparing the last three years of a guidelines use to allow for implementation delays.

311

312 Table 3 – Incidence rate ratios of admissions by year and socioeconomic quintile.

	IRR [95% CI}									
Deprivation Quintile	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Least deprived 0-20%	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
less deprived 20-40%	1.16 (1.12,1.21)	1.05 (1.01,1.09	1.09 (1.05-1.13)	1.13 (1.09-1.17)	1.10 (1.06-1.14)	1.13 (1.09. 1.18)	1.14 (1.10-1.18)	1.08 (1.04,1.12)	1.08 (1.04-1.12)	1.07 (1.03-1.11
Median Deprived 40-60%	1.32 (1.27,1.37)	1.20 (1.16,1.25)	1.18 (1.13,1.22)	1.22 (1.17-1.27)	1.24 (1.20-1.29)	1.25 (1.21-1.30)	1.24 (1.19-1.28)	1.21 (1.16,1.25)	1.18 (1.14-1.22)	1.13 (1.09-1.17
More deprived 60-80%	1.57 (1.51,1.63)	1.42 (1.37,1.47)	1.39 (1.34,1.44)	1.47 (1.42-1.53)	1.42 (1.37-1.47)	1.45 (1.40-1.50)	1.45 (1.40-1.50)	1.34 (1.30-1.39)	1.39 (1.34-1.44)	1.30 (1.26-1.35
Most deprived 80-100%	2.06 (1.99,2.13)	1.84 (1.78-1.91)	1.79 (1.72-1.85)	1.87 (1.81-1.94)	1.79 (1.73-1.85)	1.77 (1.72,1.83)	1.86 (1.80-1.92)	1.73 (1.68-1.79)	1.71 (1.65-1.77)	1.58 (1.53-1.63

313 This shows how risk of admission for the population under the age of 16 vary by year and by
314 socioeconomic quintile as measured by the index of multiple deprivations.

315

316 Table 4 – Incidence rate ratios of deaths by socioeconomic status quintile.

Deprivation Quintile	IRR (95% CI)
Least deprived 0-20%	1.00 (Reference)
less deprived 20-40%	1.26 (0.92-1.72)
Median Deprived 40-60%	1.26 (0.92-1.72)
More deprived 60-80%	1.60 (1.19-2.15)
Most deprived 80-100%	2.31 (1.77-3.02)

317 This shows how risk of death for the population under the age of 16 vary by socioeconomic quintile as
318 measured by the index of multiple deprivations. There was no significant interaction with risk of death by
319 year.

320