



OPEN ACCESS

# Selecting children for head CT following head injury

A Kemp,<sup>1</sup> E Nickerson,<sup>1</sup> L Trefan,<sup>1</sup> R Houston,<sup>2</sup> P Hyde,<sup>3</sup> G Pearson,<sup>4</sup> R Edwards,<sup>5</sup> RC Parslow,<sup>6</sup> I Maconochie<sup>7</sup>

► Additional material is published online only. To view please visit the journal online (<http://dx.doi.org/10.1136/archdischild-2015-309078>).

<sup>1</sup>College of Biomedical and Life Sciences, School of Medicine, Cardiff University, Cardiff, Wales, UK

<sup>2</sup>Research fellow CMACE (at the time of the project). Placements Manager at Kids Company, London, UK

<sup>3</sup>Paediatric Intensive Care Unit, Southampton Children's Hospital, Southampton, UK

<sup>4</sup>Consultant in Intensive Care, Birmingham Children's Hospital, Birmingham, UK

<sup>5</sup>Department of Neurosurgery, Bristol Hospital for Children, Bristol, UK

<sup>6</sup>Senior Lecturer in Epidemiology, Leeds Institute of Cardiovascular and Metabolic Medicine, School of Medicine, University of Leeds, Leeds, UK

<sup>7</sup>Paediatric Emergency Medicine Consultant, Imperial College NHS Healthcare Trust, London, UK

## Correspondence to

Professor Alison Kemp, College of Biomedical and Life Sciences, School of Medicine, Cardiff University, Cardiff, CF14 4XY, UK; [KempAM@cardiff.ac.uk](mailto:KempAM@cardiff.ac.uk)

Received 29 May 2015  
Revised 10 March 2016  
Accepted 2 April 2016  
Published Online First  
22 July 2016

## ABSTRACT

**Objective** Indicators for head CT scan defined by the 2007 National Institute for Health and Care Excellence (NICE) guidelines were analysed to identify CT uptake, influential variables and yield.

**Design** Cross-sectional study.

**Setting** Hospital inpatient units: England, Wales, Northern Ireland and the Channel Islands.

**Patients** Children (<15 years) admitted to hospital for more than 4 h following a head injury (September 2009 to February 2010).

**Interventions** CT scan.

**Main outcome measures** Number of children who had CT, extent to which NICE guidelines were followed and diagnostic yield.

**Results** Data on 5700 children were returned by 90% of eligible hospitals, 84% of whom were admitted to a general hospital. CT scans were performed on 30.4% of children (1734), with a higher diagnostic yield in infants (56.5% (144/255)) than children aged 1 to 14 years (26.5% (391/1476)). Overall, only 40.4% (984 of 2437 children) fulfilling at least one of the four NICE criteria for CT actually underwent one. These children were much less likely to receive CT if admitted to a general hospital than to a specialist centre (OR 0.52 (95% CI 0.45 to 0.59)); there was considerable variation between healthcare regions. When indicated, children >3 years were much more likely to have CT than those <3 years (OR 2.35 (95% CI 2.08 to 2.65)).

**Conclusion** Compliance with guidelines and diagnostic yield was variable across age groups, the type of hospital and region where children were admitted. With this pattern of clinical practice the risks of both missing intracranial injury and overuse of CT are considerable.

## INTRODUCTION

Every year an estimated 400 000 children younger than 15 years attend the emergency department with head injury and 35 000 children are admitted to hospital (International Classification of Diseases, Revision 10:S00-02, S06-09) in England. Although the majority of these head injuries are minor, an estimated 5% of those who are admitted to hospital sustain intracranial injuries (ICIs).<sup>1 2</sup>

Early head CT has high diagnostic specificity for ICI<sup>3</sup> and there are several clinical decision rules to determine which children should be imaged.<sup>4 5</sup> The Children's Head Injury Algorithm for the Prediction of Important Clinical Events (CHALICE)<sup>6</sup> underpins the National Institute for Health and Care Excellence (NICE) Head Injury Guidelines 2007 (figure 1) (updated in 2014<sup>7</sup>) which aims to identify clinically important brain injury to ensure early intervention while allowing those at low risk to be discharged without

## What is already known on this topic

- Early head CT has high diagnostic specificity for intracranial injury.
- National Institute for Health and Care Excellence (NICE) Head Injury Guidelines aim at identifying children at risk of clinically significant brain injury.

## What this study adds

- Approximately one-third of children admitted to hospital with head injury have a head CT scan.
- Diagnostic yield was twice as great in infants (<1-year-old) than older children.
- Only 40% of children with at least one of four NICE indications for CT had a CT scan, which was less likely to be done in children <3 years or in a general hospital where there was considerable variation between healthcare regions.

investigation, avoiding unnecessary exposure to radiation and cost to the healthcare service.

In 2009, as part of the child health confidential enquiry programme, the Centre for Maternal and Child Enquiries (CMACE) was commissioned by the Department of Health and the funding bodies of Wales, Northern Ireland, the Channel Isles and the Isle of Man to review morbidity and mortality in children admitted to hospital with head injury, to review the effect of early management on outcomes and to identify avoidable factors associated with adverse outcomes. The aim of this analysis was to explore the extent to which children with head injury were investigated with head CT, to identify factors that influenced the rate of CT uptake and yield and to compare practice against the NICE clinical guidelines.

## METHODS

Data for this cross-sectional study of children younger than 15 years who were admitted for more than 4 h with a head injury were collected from 90% of hospitals in England, Wales, Northern Ireland and the Channel Islands from September 2009 to February 2010. Children who received any treatment or observation in a hospital inpatient area were included, whereas those with superficial or facial injuries were excluded.

Data were collected using proformas (see online supplementary appendix 1) completed by a



CrossMark

**To cite:** Kemp A, Nickerson E, Trefan L, et al. *Arch Dis Child* 2016;**101**:929–934.

**Figure 1** National Institute for Health and Care Excellence (NICE) Head Injury Guidelines 2007: recommendations in place for this study population, indicating when a CT should be performed in a child with a head injury.<sup>7</sup>

#### NICE recommendations for when to request a CT immediately if < 16 years

- Witnessed loss of consciousness lasting > 5 minutes
- Amnesia (antegrade or retrograde) lasting > 5 minutes
- Abnormal drowsiness
- Three or more discrete episodes of vomiting
- Clinical suspicion of non-accidental injury
- Post-traumatic seizure but no history of epilepsy
- Age > 1 year: GCS < 14 on assessment in the emergency department
- Age < 1 year: GCS (paediatric) < 15 on assessment in the emergency department
- Suspicion of open or depressed skull injury or tense fontanelle
- Any sign of basal skull fracture
- Focal neurological deficit
- Age < 1 year: presence of bruise, swelling or laceration > 5cm on head
- Dangerous mechanism of injury (high-speed road traffic accident either as pedestrian, cyclist or vehicle occupant, fall from > 3m, high-speed injury from a projectile or an object)

designated local coordinator and collected monthly from each participating hospital. Data fields that were less than 75% complete were excluded from the analysis.

Data recorded included demographics, clinical information, type and healthcare region of the admitting hospital. Hospitals were categorised according to the specialist facilities offered and the designation of major trauma centres introduced in April 2012: General Hospital (GH); Children's Hospital with paediatric intensive care unit (PICU); Adult Major Trauma Centre; Adult and Children's Major Trauma Centre and Children's Major Trauma Centre.<sup>8</sup>

Descriptions of injury mechanisms were coded as listed in table 1 and cases of suspected physical abuse were documented.

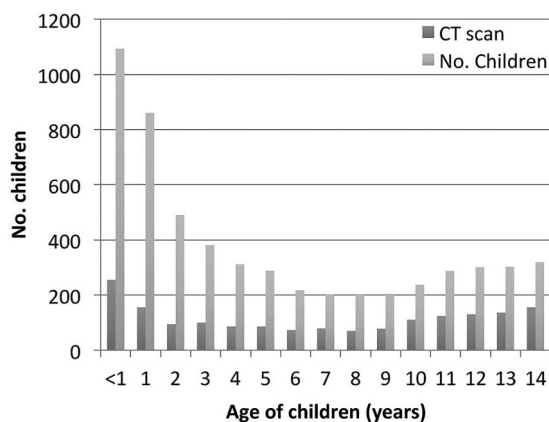
The level of consciousness was recorded according to the Glasgow Coma Scale (GCS)<sup>9</sup> reported in the emergency department. When GCS was missing, Alert, Voice, Pain, Unresponsive (AVPU) scores<sup>10</sup> were often available. These data were combined to create four categories, 'GCS=15/Alert', 'GCS=13-14', 'GCS=9-12/responsive to voice' and 'GCS≤8/ response to pain or unresponsive', based on an equivalence study by Mackay *et al.*<sup>11</sup>

ICI and/or skull fracture sustained were documented from radiology reports. CT results were grouped into four categories: normal; ICI (injury to the brain or surrounding extra-axial structures, with or without skull fractures) or depressed fracture; simple skull fracture (a linear non-depressed fracture with no

**Table 1** Cause of injury: CT scan rate and result of CT scan for each causal category for 5574 children where their CT status was recorded

Mechanism of injury	Total	Proportion who had CT (n)	Median age (years) (range)	CT result ; CT scans that were abnormal (%) (n)				
				Missing (n)	Normal	ICI and/or depressed #	Simple #	Other
Assault	118	33.9% (40)	13 (0-14.9)	8	45% (18)	25% (10)	5% (2)	5% (2)
Cycling	267	43.8% (117)	11.5 (0.8-14.8)	9	70% (82)	17.1% (20)	4.3% (5)	0.9% (1)
Fall from <1 m or <5 stairs	1822	22% (402)	2.1 (0-14.9)	40	65.7% (264)	11.2% (45)	10.7% (43)	2.5% (10)
Fall from >1 m or >5 stairs	994	30.3% (301)	2.1 (0-14.8)	22	62.1% (187)	18.6% (56)	9% (27)	3% (9)
Fall, height unknown	673	30.2% (204)	4.2 (0.1-14.9)	21	65.7% (134)	11.8% (24)	10.3% (21)	2% (4)
MVA (not pedestrian)	88	54.5% (48)	6.5 (0-14.9)	2	56.3% (27)	31% (15)	4.2% (2)	4.2% (2)
MVA: struck by car (child cyclist)	35	51.4% (18)	12.2 (1-14.9)	0	44.4% (8)	33.3% (6)	22.2% (4)	0
MVA: struck by car (child pedestrian)	273	55.8% (158)	11.3 (0-14.9)	22	49.4% (78)	23.4% (37)	8.9% (14)	4.4% (7)
Impact injuries	684	25.4% (174)	3.7 (0.1-14.8)	15	72.4% (126)	10.3% (18)	6.9% (12)	1.7% (3)
Other recreational	150	39.3% (59)	8.7 (0.4-14.9)	5	61% (36)	15.3% (9)	11.9% (7)	3.4% (2)
Sport	358	44.4% (159)	12.4 (0-14.9)	10	79.2% (126)	8.8% (14)	3.1% (5)	2.5% (4)
Not known	112	52% (54)	1.4 (0-14.7)	6	43.4% (23)	28.3% (15)	11.1% (6)	7.5% (4)
<b>Total</b>	<b>5574</b>	<b>31.1% (1734)</b>		<b>160</b>	<b>64% (1109)</b>	<b>(15.5%) 269</b>	<b>(8.5%) 148</b>	<b>(2.8%) 48</b>

A total of 126 cases were excluded as it was not known if CT scan was performed. ICI, intracranial injury; MVA, motor vehicle accident.



**Figure 2** Bar diagram showing the age in years of 5700 children admitted to hospital with a head injury and number who had CT scan (1734).

underlying ICI) and ‘other’ (incidental findings (eg, subarachnoid cysts, congenital anomalies)).

### Data analysis

The proportion of children (with 95% CIs) with each of the following four NICE guideline indicators<sup>7</sup> who had a CT scan is described: GCS of <15 for those <1 year, and of <14 for those >1 year of age, loss of consciousness, suspicion of non-accidental injury (NAI), dangerous mechanism of injury (motor vehicle accident (MVA), high fall). The extent to which the individual indicators were predictors of abnormal CT was calculated. Children were identified who had at least one of these indicators and the observed:expected ratios (based on the 2007 NICE guidance) of CT were plotted on funnel plots according to the age of the child, hospital type and Health Commissioning Board for England and the regions of Wales and Northern Ireland. The time to CT scan, the duration of admission and the number of children who were readmitted with the head injury are described. 95% CIs were used for comparisons of proportions.

CMACE obtained section 251 approval to gather patient information without consent and the project was approved. R&D or clinical governance forms were obtained from all participating hospitals. Ethical and section 251 approvals were renewed when the project was transferred to Cardiff University for analysis by the Central Manchester Research Ethics Committee prior to the study and were updated in July 2012 (Ref 09/H1008/74).

### RESULTS

A total of 5700 children were included in the study (median age 49 months) (figure 2). Peak prevalence was in infants younger than 1 year. The majority of children 84% (4768) were admitted to a GH, 3.4% of children (191) to a hospital equivalent to a children’s major trauma centre, 7.3% of children (417) to an Adult and Children’s Major Trauma Centre, 3.3% of children (160) to a hospital designated an Adult Major Trauma Centre and 3.3% of children (164) to a Children’s Hospital with PICU.

Overall 30% (1734) of the children had a head CT. This was performed at a median time of 1.5 h (range 0–35.8 h) after the first clinical assessment in the emergency department, 33% (297) were done within an hour. The time to CT scan was shorter in those with GCS of <15 (median time: GCS 15=100 min, GCS 13–14=69 min, GCS 9–12=72 min, GCS ≤8=65 min). All except 10 of the 385 children who were transferred to a second hospital had a CT scan in the first hospital. Two-thirds (64% (1109/1734)) of CT scans were reported as normal, 15% (269) had ICI or depressed fracture, 8.5% (148) a simple fracture and 2.8% (48) had other findings (results were missing 9% (160)).

The proportion of children who had a CT scan varied by mechanism of injury and was greatest for children who had experienced a MVA. These children were most likely to have an abnormality on CT scan (table 1). Children who had low falls were least likely to have a CT or an abnormal CT (table 1). Child abuse was suspected in 256 cases; 48% (122) had a CT scan, 36% (44/122) of whom had ICI or depressed fracture and 15% (18/122) had a simple skull fracture. The majority of these children (82% (36/44)) were aged <1 year.

The GCS/AVPU score was recorded in the emergency department for 5168 children (91%) (GCS in 4182 children and AVPU in 986 children). Tables 2 and 3 confirm that the majority, 79% of children (4522) had a ‘GCS of 15/Alert’. CT scan was more likely to be performed in older children and in children with a greater level of impaired consciousness (table 2). Of the 70 infants (<1 year) who had a GCS of <15/Alert and were eligible for CT, only 50% (35/70) had the investigation, of whom 72% (95% CI 55% to 84%)(25/35) were abnormal. Of infants who had a ‘GCS of 15/Alert’, 20.7% (181/876) had CT and 53% (95% CI 46% to 60%) (96/181) had an abnormality recorded. For children older than 1 year, a total of 293 children had a GCS <14 (or AVPU of V, P or U), 77% (225/293) had a CT and 47% (95% CI 41% to 54%) (106/225) had an abnormality detected; for children with a GCS of 14–15 or ‘Alert’, 30% (1170/3922) had a CT and the positive yield was 23% (95% CI 20% to 25%) (264/1170).

**Table 2** CT scanning rates according to GCS/AVPU and age group

	Age (years)				Missing age	Total
	<1	1–4	5–9	10–14		
GCS≤8 AVPU=‘U’ or ‘P’	13/18 (72%)	25/38 (66%)	15/16 (94%)	37/39 (95%)	0	90/111 (80%)
GCS 9–12 AVPU=‘V’	6/13 (46%)	26/42 (62%)	28/34 (82%)	42/52 (81%)	1/1	103/142 (72%)
GCS 13–14	16/39 (41%)	39/93 (42%)	64/87 (74%)	139/174 (80%)	0	258/393 (66%)
GCS=15 AVPU=A	181/876 (20.7%)	316/1652 (19%)	261/891 (29%)	403/1096 (37%)	2/7	1163/4522 (26%)
GCS/AVPU not recorded in the notes	39/147 (26.5%)	29/217 (13.4%)	18/82 (22%)	34/86 (39.5%)	0	120/532 (22.6%)
<b>Total</b>	<b>255/1093 23% (21–26)</b>	<b>435/2042 21% (20–23)</b>	<b>386/1110 35% (32–37.6)</b>	<b>655/1447 45% (42.7–47.8)</b>	<b>3/8</b>	<b>1734/5700 30.4%</b>

AVPU, Alert, Voice, Pain, Unresponsive; GCS, Glasgow Coma Scale.

**Table 3** Comparison of the number and proportion of CT outcomes according to GCS/AVPU for children aged <1 year (CT recommended if GCS is <15) and older children (CT recommended if GCS is <14)

CT category	GCS/AVPU in <1 year			GCS/AVPU in > 1 year			Total
	15/ 'Alert'	<15:V/P/U	GCS/AVPU not recorded	14–15: 'Alert'	<14:V/P/U	GCS/AVPU not recorded	
Normal	78 (43.1%)	7 (20%)	14 (35.9%)	844 (72.1%)	113 (50.2%)	52 (64.2)	1108 (+1*) (64%)
ICI and/or depressed #	37 (20.4%)	19 (54.3%)	14 (35.9%)	124 (10.6%)	64 (28.4%)	10 (12.4%)	268 (+1*) (15.5%)
Simple #	40 (22.1%)	2 (5.7%)	8 (20.5%)	67 (5.7%)	21 (9.3%)	9 (11.1%)	147 (+1*) (8.5%)
Other†	9 (5%)	1 (2.9%)	0	33 (2.8%)	4 (1.8%)	1	48 (2.8%)
Abnormality but not described	10 (5.5%)	3 (8.6%)	1	40 (3.4%)	17 (7.6%)	1	72 (4.2%)
Result not recorded	7 (3.9%)	3 (8.6%)	2	62 (5.3%)	6 (2.7%)	8 (10%)	88 (5.1%)
Total	181	35	39	1170	225	81	1731 (3*)

\*The age of three children was not recorded.

†Other findings included extracranial soft tissue swelling (12) aberrant or incidental structural findings(14), cysts (8) for example, widened subdural space, soft tissue swellings, cephalohaematoma (3), facial bone fractures (4), wide subarachnoid space or hydrocephalus (7).

AVPU, Alert, Voice, Pain, Unresponsive; ICI, intracranial injury; GCS, Glasgow Coma Scale.

Loss of consciousness at the time of the incident was reported in 18% of children (1018/5700); however, the duration was not recorded. Of these children, 47% (474/1018) had a CT scan, 37% (177/474) were abnormal, 37% (66/177) had ICI or a depressed fracture, 39% (70/177) a simple fracture, 7.9% (14/177) had other findings and 15% (27/177) had abnormal findings but details were not recorded.

At least one of the following four indicators (NICE guidelines) for a CT scan was present in 2437 children; GCS <15 for a child <1 year or <14 for an older child, loss of consciousness, a dangerous mechanism of injury or a suspicion of NAI. Of these children, 40% (984) had CT; 68% (666) were normal, 20% (201/984) showed an ICI or depressed fracture, 8.9% (88/984) had a simple fracture and 3% (29) showed other findings. Funnel plots (figure 3) show that children older than 3 years were significantly more likely than younger children to have CT (OR 2.3 (95% CI 2.1% to 2.6%)). Those admitted to GHs were significantly less likely to have CT than those admitted to children's hospitals or major trauma centres (OR 0.5 (95% CI 0.4 to 0.6)). Among the children admitted to a GH, there was a considerable variation in CT scanning rates across Commissioning Boards and healthcare regions; only the London-based GHs had a CT rate that complied with the 2007 NICE guideline indicators that were evaluated. The reason why CT scans were not done in the 1453 children who had an indication to do so was poorly recorded. A total of 903 stated that CT was not clinically indicated; no reason was recorded in the notes in 507; other reasons included the fact that skull X-ray deemed sufficient (four), child non-compliant (eight), machinery not working (four), child died or was unstable (four) admitted for observation (six) previous CT (three) radiologist refused the CT (four) and for multiple reasons (10).

### Clinical pathways and outcomes

Children who had normal CT findings spent significantly longer periods (mean: 23.9 h (SD=37.6 h)) in hospital under observation than those who did not have CT (mean 14.7 h (SD=29.2 h)) ( $p \leq 0.05$ ). Children with ICI or depressed fracture spent a mean of 88.5 h (SD 120.9 h) in hospital; those with a simple fracture spent 45.2 h (SD 40.6 h) and those with other findings spent 63.5 h (SD 142.6 h). About 1% (57) of children were admitted for treatment to neurosurgery units. Twenty-four children died (0.4%). Fourteen deaths were from MVAs, 11

died at the scene of incident or while in the emergency department prior to having a CT. The mortality rate among those who had a CT scan was 7.5% (13/1734).

In total, 4.6% of the children (265) were readmitted within 72 h of their first presentation for the same head injury (median age 5 years). Of these, six had a CT scan on first admission, all were normal apart from one child who had a facial fracture, four of the six children were rescanned with no change to the findings. Ninety children (34%) had a CT scan for the first time on their second admission, 34% (32/90) were abnormal (six simple fractures, 21 ICI with or without a skull fracture or depressed fractures, five had other findings). There was no significant difference between the age distribution of these cases and the overall dataset. The re-attendance rate was significantly greater for those children who did not have a CT at their first attendance (6.5% (259/3966)) than those who did (0.3% (6/1734)) (OR 20 (95% CI 8.9 to 45)).

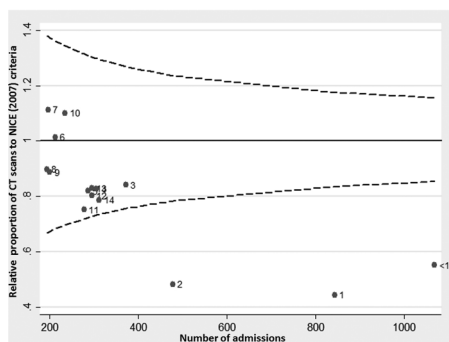
### DISCUSSION

One-third of children admitted to hospital with head injury had a CT scan, 15.5% of whom had traumatic brain injury or depressed fracture. However, 60% of children who had at least one of four NICE guideline indicators did not have any neuroimaging; NICE guidelines were therefore not followed in the majority of cases. CT scan rates were particularly low in children younger than 3 years and those admitted to GHs. The latter showed a strong regional variation.

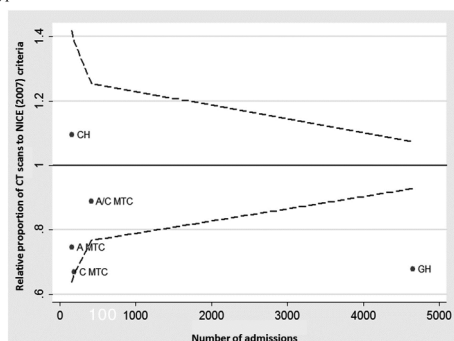
This is the largest national dataset to evaluate adherence to NICE head injury guidelines for neuroimaging. The study has several limitations. Data were collected from multiple centres. However, the same proforma was used in all centres and data were extracted at each centre by a dedicated local coordinator to ensure a standardised approach. The data collection only included a proportion of the indicators for a CT scan cited in NICE guidelines 2007 and we were unable to analyse how seizures, amnesia, more than three discrete episodes of vomiting, focal neurology or facial bruising influenced CT scan rates.

There were missing data and data inconsistencies that had to be accounted for. The main data fields analysed were more than 90% complete and unlikely to affect the statistical significance of the results provided. The population within this study was confined to hospital admissions of more than 4 h duration. It must be appreciated that this population represents a proportion

## A Age

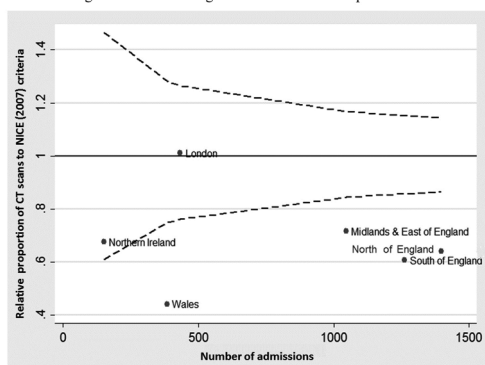


## B Hospital type



Hospital classification according to facilities offered: AMTC - Adult Major Trauma Centre, A/CMTC - Adult and Children's Major Trauma Centre, CMTC - Children Major Trauma Centre, CH - Children Hospital, GH - General Hospital

## C Health Commissioning Board or health region for the General Hospitals



**Figure 3** Funnel plots showing the CT scan rate for children with at least one of four indicators for CT (National Institute for Health and Care Excellence (NICE) guidance) by (A) age, (B) hospital type, (C) Health Commissioning Board or health region for the General Hospitals.

of the large number of children who attend emergency departments every year with minor head injuries, all of whom must be assessed for injury severity and are subject to NICE head injury guidelines.

The ultimate test of the CT guideline is whether it identifies clinically important brain injury to ensure early intervention and improve clinical outcome. One in 100 children was identified as having a need for neurosurgery. This was twice the number reported by Marlow *et al*<sup>2</sup> who identified a constant rate of neurosurgery (0.4%) from their analysis of routinely collected hospital episode data from 2000 to 2011; however, children in this study represented a subset (admissions >4 h) of the population within their study. While the mortality rate was greater in those who had CT than in those who did not, this must be balanced against injury severity that triggered investigation and

may not be a marker of late intervention. CT imaging was associated with a reduced readmission rate but the length of hospital stay was greater in those who had a normal CT than in those who had no CT, suggesting that clinicians were not always clinically reassured by normal neuroimaging findings. Caution must be exerted when interpreting these findings as markers of efficacy of a guideline that was applied inconsistently.

The overall CT rate was higher than that proposed by Dunning *et al*<sup>6</sup> when they developed the CHALICE rule (2000–2002). They and others predicted that a CT rate of around 14% would be required to pick up 98% of clinically significant head injuries.<sup>12–13</sup> Comparison of CT rates between studies is difficult due to the variation of study population inclusion criteria, age ranges, injury severity and the point along the clinical pathway where data were collected. CT rates quoted varied from 12.8% to 58%.<sup>2, 14–16</sup> The higher CT rate in older than younger children was consistent with a US study of children with mild head injury<sup>16</sup> and may be influenced by the ease of assessing the GCS, the higher prevalence of 'dangerous mechanisms of injury' or because performing a CT scan is technically easier.

While improved compliance for adult head CT has been demonstrated following the introduction of NICE guidelines, a reluctance to adhere to the NICE recommendations for children has been identified.<sup>17</sup> Data collected in 2008 showed that 68.7% of children in one teaching hospital and 77.1% in a busy district GH with indicators for a head CT did not have one.<sup>17</sup> The low compliance with NICE guidelines in young children (<3 years) would be consistent with a preference to admit these children to hospital for a period of observation rather than perform CT. It is possible that clinicians were reluctant to risk exposing very young children to cranial irradiation. Recent research estimates 'one excess case of leukaemia and one excess brain tumour per 10 000 patients' within 10 years of having a CT for a child aged <10 years<sup>18</sup> and a lifetime excess risk of cancer of one cancer per 1000 head CT scans for children younger than 5 years (one cancer per 2000 scans for exposure at age 15 years).<sup>19</sup> These risks will always influence clinical decisions but must be balanced against the immediate benefits and diagnostic accuracy of CT when assessing a child with potentially serious head injury.

While there was a low uptake of CT in the youngest children, there was a significantly higher yield of cranial and ICI abnormalities than the older children, particularly among infants. It could be argued that the potential to miss cranial and ICIs in this young age group is high. However, the counterargument is that the practice of clinical assessment and observation when balanced against the risks of sedation or radiation dosage associated with CT in these young children is more appropriate and a greater proportion of the correct children are receiving a CT scan.

For the older age group, CT is potentially overused.<sup>20</sup> A considerable number of CTs were performed in children older than a year with a GCS of 14–15 with a yield of ICI or depressed fracture little more than 10%. This pattern of CT suggests that a modification of NICE guidelines in this age group could ensure that the right children are investigated and the number of children receiving unnecessary CT scans is reduced. It is possible that this will happen once the changes in NICE head injury guidelines 2014<sup>7</sup> are embedded in clinical practice where loss of consciousness and dangerous mechanism of injury must be present together or in association with at least one other feature before CT is indicated.

The 2007 NICE guidelines recommend immediate CT scan if one of the listed recommendations was present (figure 1) and while an explicit time scale was not given in 2007 guidelines for children, it is assumed that the adult standard applies and CT

should be done within an hour. These data show that this standard was not being met in the majority of cases. The 2014 guidelines<sup>7</sup> have stratified clinical indicators to identify high-risk children where a CT scan should take place within the hour and has the potential to improve uptake.

These data confirm that when children had a CT the diagnostic yield for ICI was as high as 72% for infants with GCS of <15 and 47% for older children with a GCS of <14. However, the debate continues as to when children with mild impairment (GCS of 13–15) should have a CT. Many of the clinical decision rules are designed to inform this specific decision, for example, PECARN and CATCH.<sup>4 5</sup> A recent validation study of 1009 cases showed that PECARN had the greatest sensitivity and identified 100% of the 21 cases of traumatic brain injury in children presenting mild head injury; CHALICE missed cases having a sensitivity of 84% and a specificity of 85% for the same sample.<sup>21</sup> However, definitive answers to these questions may be provided from the Paediatric Research in Emergency Departments International Collaborative research network ongoing prospective trial.<sup>22</sup>

The low CT scan rate in GHs may reflect paediatric anaesthetic cover, a reluctance to sedate children for imaging, limited out-of-hours access to CT imaging or lack of paediatric emergency medicine expertise, poorer training and thus poorer adherence to national clinical guidelines. Recent studies have shown substantial variation in the use of CT scan across different hospital settings.<sup>15 20 23</sup>

In summary, we have shown that compliance with the NICE 2007 head injury guidelines was variable and generally poor. The more recent 2014 guidelines include a second tier of indicators which permit a 4 h observation followed by CT if the child deteriorates; this stratified approach is potentially more complicated to apply but is supported by the data we present. It is important that the implementation and effect of the revised guidelines are studied so that infants and children with head injury can benefit fully from an evidence-based approach to their care.

**Twitter** Follow Richard Edwards at @paedneurosurg

**Acknowledgements** This project/audit was commissioned by the Healthcare Quality Improvement Partnership as part of the National Clinical Audit and Patient Outcomes Programme (NCAPOP). This is one of a series of forthcoming publications using the study data. Additional members of the original CMACE Head Injury External advisory group: Professor Robert Tasker, Paediatrics, University of Cambridge; Dr Rosemary Arthur, Consultant Paediatric Radiologist, Leeds (British Society Paediatric Radiology); Dr Fiona Lecky, Research Director TARN, Senior Lecturer, Honorary Consultant Emergency Medicine, Manchester; Dr Fiona Moore, Medical Director London Ambulance Service; Dr Kevin Morris, Director PICU Birmingham Children's Hospital; Lisa Turan, Chief Executive Child Brain Injury Trust; Girkamal Virdi, Assistant Head of Clinical and Audit Research, London Ambulance Service and Mark Woolcock, Emergency Medical Practitioner and Emergency Specialist Service, South Western Ambulance Service, NHS Foundation Trust.

**Contributors** EN: Undertook the data analysis and wrote the first drafts of the paper. LT: Undertook the statistical analysis. RH: Designed the original data collection tools, supervised data collection, cleaning and data entry of the data collected within the original confidential enquiry of head injury (CMACE). GP: Director of the CMACE confidential enquiry and supervised the design and running of the project and has been involved in editing this manuscript. RE, PH, IM, RCP: Members of the project Independent Advisory Board and gave advice and editorial supervision at regular intervals during the study analysis. AK: principal investigator on the data analysis, coordinated the study writing, checked and edited the manuscript, agreed the concept and methodology of this particular analysis.

**Funding** Health Quality Improvement Partnership.

**Competing interests** IM is supported by the National Institute for Health Research (NIHR) Biomedical Research Centre based at Imperial College Healthcare NHS Trust and Imperial College London.

**Ethics approval** Central Manchester Research Ethics Committee prior to the study and updated in July 2012 (Ref 09/H1008/74).

**Provenance and peer review** Not commissioned; externally peer reviewed.

**Open Access** This is an Open Access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited and the use is non-commercial. See: <http://creativecommons.org/licenses/by-nc/4.0/>

## REFERENCES

- Health and Social Care Information Centre. Hospital Episode Statistics, Admitted Patient Care, England—2012–13. Diagnosis. 2013. <http://www.hscic.gov.uk/catalogue/PUB12566/hosp-epis-stat-admi-diag-2012-13-tab.xlsx> (accessed 20 Feb 2015).
- Marlow R, Mytton J, Maconochie IK, *et al.* Trends in admission and death rates due to paediatric head injury in England, 2000–2011. *Arch Dis Child* 2015;100:1136–40.
- Pickering A, Harnan S, Fitzgerald P, *et al.* Clinical decision rules for children with minor head injury: a systematic review. *Arch Dis Child* 2011;96:414–21.
- Kuppermann N, Holmes JF, Dayan PS, *et al.* Identification of children at very low risk of clinically-important brain injuries after head trauma: a prospective cohort study. *Lancet* 2009;374:1160–70.
- Osmond MH, Klassen TP, Wells GA, *et al.* CATCH: a clinical decision rule for the use of computed tomography in children with minor head injury. *CMAJ* 2010;182:341–8.
- Dunning J, Daly JP, Lomas JP, *et al.* Derivation of the children's head injury algorithm for the prediction of important clinical events decision rule for head injury in children. *Arch Dis Child* 2006;91:885–91.
- National Institute for Health and Clinical Excellence (NICE). Head injury: Triage, assessment, investigation and early management of head injury in children, young people and adults. 2014. <http://www.nice.org.uk/guidance/cg176> (accessed 20 Feb 2015).
- National Health Service (NHS). Major trauma centres. 2012. <http://www.nhs.uk/NHSEngland/AboutNHSservices/Emergencyandurgentcareservices/Documents/2012/map-of-major-trauma-centres-2012.pdf> (accessed 20 Feb 2015).
- Teasdale G, Jennett B. Assessment of coma and impaired consciousness. A practical scale. *Lancet* 1974;304:81–4.
- McNarry AF, Goldhill DR. Simple bedside assessment of level of consciousness: comparison of two simple assessment scales with the Glasgow Coma scale. *Anaesthesia* 2004;59:34–7.
- Mackay CA, Burke DP, Burke JA, *et al.* Association between the assessment of conscious level using the AVPU system and the Glasgow coma scale. *Prehospital Immediate Care* 2000;4:17–19.
- Elliot RR, Sola Gutierrez Y, Harrison R, *et al.* Cautious observation or blanket scanning? An investigation into paediatric attendances to an emergency department after head injury. *Injury* 2011;42:896–9.
- Ghosh R, Docherty E, Schickerling S, *et al.* Application of the 2007 NICE guidelines in the management of paediatric minor head injuries in a UK emergency department. *Emerg Med J* 2012;29:197–200.
- Lyttle MD, Cheek JA, Blackburn C, *et al.* Applicability of the CATCH, CHALICE and PECARN paediatric head injury clinical decision rules: pilot data from a single Australian centre. *Emerg Med J* 2013;30:790–4.
- Mannix R, Bourgeois FT, Schutzman SA, *et al.* Neuroimaging for pediatric head trauma: do patient and hospital characteristics influence who gets imaged? *Acad Emerg Med* 2010;17:694–700.
- Mannix R, Meehan WP, Monuteaux MC, *et al.* Computed tomography for minor head injury: variation and trends in major United States pediatric emergency departments. *J Pediatr* 2012;160:136–9.e1.
- Mooney JS, Yates A, Sellar L, *et al.* Emergency head injury imaging: implementing NICE 2007 in a tertiary neurosciences centre and a busy district general hospital. *Emerg Med J* 2011;28:778–82.
- Pearce MS, Salotti JA, Little MP, *et al.* Radiation exposure from CT scans in childhood and subsequent risk of leukaemia and brain tumours: a retrospective cohort study. *Lancet* 2012;380:499–505.
- Berrington de González A, Mahesh M, Kim KP, *et al.* Projected cancer risks from computed tomographic scans performed in the United States in 2007. *Arch Intern Med* 2009;169:2071–7.
- Stanley RM, Hoyle JD, Dayan PS, *et al.* Emergency department practice variation in computed tomography use for children with minor blunt head trauma. *J Pediatr* 2014;165:1201–6.e2.
- Easter JS, Bakes K, Dhaliwal J, *et al.* Comparison of PECARN, CATCH, and CHALICE rules for children with minor head injury: a prospective cohort study. *Ann Emerg Med* 2014;64:145–52.
- Babl FE, Lyttle MD, Bressan S, *et al.* A prospective observational study to assess the diagnostic accuracy of clinical decision rules for children presenting to emergency departments after head injuries (protocol): the Australasian Paediatric Head Injury Rules Study (APHIRST). *BMC Pediatrics* 2014;14:1–10.
- Marin JR, Weaver MD, Barnato AE, *et al.* Variation in emergency department head computed tomography use for pediatric head trauma. *Acad Emerg Med* 2014;21:987–95.