CT head imaging in patients with head injury who present after 24 h of injury: a retrospective cohort study

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ABSTRACT

Background National Institute for Health and Care Excellence guidelines used to triage patients with head injury to CT imaging are based on research conducted in populations presenting within 24 h of injury.

We aim to compare guideline use, and outcomes, in patients with head injury that undergo CT imaging presenting within, and after 24 h of injury.

Methods ED trauma CT head scan requests over a period of 6 months were matched to ED records. Case note review of adult patients with head injury that had undergone CT imaging was completed. Logistic regression was used to assess whether presentation after 24 h affected the guideline's ability to predict significant injuries.

Results 650 case records were available for analysis. 8.6% (56/650) showed a traumatic abnormality, 1.5% (10/650) required neurosurgery or died. 15.5% (101/650) of CT scans were for patients presenting after 24 h. 8.4% (46/549) of those presenting within, and 9.9% (10/101) of those presenting after 24 h had traumatic CT abnormalities.

The sensitivity of the guidelines for intracranial injuries was 98% (95% CI 87.0% to 99.9%) in those presenting within 24 h and 70% (95% CI 35.4% to 91.9%) in those presenting after 24 h of injury. The presence of a guideline indication statistically predicted significant injury, and this was unaffected by time of presentation.

Conclusions Patients with head injury presenting after 24 h of injury are a clinically significant population. Existing guidelines appear to predict traumatic CT abnormalities irrespective of timing of presentation. However, their sole use in patients presenting after 24 h may result in significant injuries not being identified.

Key messages

What is already known on this subject

- Almost all decision rule head injury research has been conducted on patients presenting within 24 hours of injury. Little evidence exists about the risk of significant injury in delayed presentation head injury populations. It may be lower, as clinical deterioration in patients with intra-cranial haemorrhage usually occurs within 24 hours of injury. Alternatively, delayed presentation head injury patients may be a higher risk self-selecting group presenting due to the worsening or persistence of symptoms.

What this study adds

- Patients presenting after 24 hours of injury appear to be a clinically significant population and accounted for 15.5% of adult head trauma CT scans in our study. A similar prevalence of significant traumatic pathology was found in patients presenting within and after 24 hours that underwent cranial CT for the investigation of a head injury. The NICE guidelines were found to be less sensitive in patients presenting after 24 hours of injury, although this was not statistically significantly.

INTRODUCTION

Head injuries account for an estimated 1.4 million annual ED attendances in England and Wales.[1] Ninety-five per cent of such attendances are for minor/mild head injuries.[1] Only 1% of these patients have neurosurgical interventions and 5% of patients have injuries of sufficient significance to warrant hospital admission.[2] Research in this area has concentrated on developing clinical decision rules to aid the clinical risk stratification of patients with mild/minor head injury into: those who can be discharged on the basis of their clinical history and examination; and those who require a CT head scan to rule out significant intracranial pathology. Decision-rule research has almost exclusively been conducted on patients presenting within 24 h of injury.[3] In the UK, the National Institute for Health and Care Excellence (NICE) guidelines are used to aid this risk assessment. They are based upon the Canadian CT Head Rule (CCHR), and this is used widely internationally.[1] This was derived and validated in patients presenting within 24 h of injury.[3–6]

Patients presenting after 24 h of injury are a potentially distinct subpopulation. They could be at lower risk, as there is evidence that patients with mild/minor head injury who have injuries requiring neurosurgery will deteriorate within 24 h.[7–9] Alternatively, they could be a self-selecting higher-risk group attending due to the worsening or persistence of symptoms.[10] The lack of research about this group is acknowledged in the research literature.[10–12] There are few studies that even estimate the size of this population. One study found that approximately a third of a cohort of patients presenting after 4 h of injury presented after 24 h.[11] In contrast, an older study found only 6.7% of ED patients with head injury to present after 12 h of injury.[13]

If patients presenting after 24 h represent a lower-risk group, then a lower comparative rate of intracranial injury would be expected. A single study has found that comparable risk factors to those present in NICE guidelines are predictive of traumatic CT abnormalities in patients with head injury presenting after 4 h of injury.[11] However, how well the guidelines identify injuries in patients presenting after 24 h, a group where the CCHR has not been validated, has not been assessed.

Aim

The aim of this study is to compare guideline use and outcomes in patients with head injury that undergo CT imaging presenting within and after 24 h of injury.

The specific objectives were to:

1. Estimate the proportion of adult head-trauma CT scans performed for patients presenting after 24 h of injury.
2. Compare the prevalence of traumatic CT findings in patients with head injury who undergo CT head imaging presenting within and after 24 h of injury.
3. Compare the use and sensitivity of the 2007 NICE guidelines in patients with head injury who undergo CT head imaging presenting within and after 24 h of injury.

METHODS

Study participants

Six months of all ED CT head scan requests at Hull Royal Infirmary (HRI) from November 2011 were available through the electronic requesting system. These were reviewed and all requests obviously not for head trauma removed. The remaining electronic requests were matched to the HRI ED electronic records and reporting systems. These electronic records included: scanned ED patient encounter records; CT head scan images; CT head scan reports; patient discharge letters (including notification of cause of death to the patient's general practitioner where applicable) and operation notes. Where information was incomplete the patients' physical case notes were reviewed. Included patients had to have had a CT head scan for the sole investigation of head trauma and be over 16 years of age.

Exclusion criteria

Cranial CT scans requested as part of a trauma series were excluded. Attendances were excluded from the final analysis where the ED records were incomplete, including where timing of presentation was not possible.

Data extraction

Data extraction was undertaken, as outlined by an a priori audit protocol, for: demographic information; mechanism of injury; presence of individual NICE indications for a CT (indications based on NICE guidelines 2007); whether presentation was within or after 24 h of injury; whether the patient was reattending with an existing injury; CT head findings; neurosurgical outcomes and death.

Outcomes

For the purposes of this study a significant CT head finding had to be of a new traumatic intracranial injury, including skull fractures, contusions and any type of intracranial haemorrhage. Existing findings and non-traumatic abnormalities were not recorded. Neurosurgical outcomes were defined as: intubation; any form of invasive intracranial pressure monitoring; craniotomy; burr hole procedure and any surgical procedure for the treatment of a skull fracture. For patients that were registered as dead, an outcome of a death associated with a head-injury attendance was counted if: they died within 18 months of attendance; and an intracranial injury associated with the attendance was documented as either a primary or contributory cause of death. This was assessed through the available electronic and physical patient records at the time of data collection (August 2014–August 2015).

Statistical analysis

Descriptive statistics (mean (SD) and n (%)) were calculated for demographic and presenting characteristics of the patients that underwent CT and by group presenting within and after 24 h of injury. The groups were compared for the outcome measures: prevalence of traumatic CT findings; whether or not there was a neurosurgical intervention and death. The proportion in each group who had an indication for the completed CT head scans was also compared. Pearson χ^2 test or Fisher's exact test are used to compare groups. The sensitivity of the guidelines for neurosurgical intervention and significant traumatic CT findings was calculated for each group. 95% CIs were calculated for outcomes of interest.

Logistic regression analysis was undertaken post hoc. Given the proportion of intracranial injuries was 8.6% and there were 650 CT head scans included in the analysis, up to five explanatory variables could be investigated.[14] For the purposes of this study two variables and one interaction were explored, with traumatic CT finding as the dependent variable and the independent variables: presence of an indication for CT head scan (coded 0,1); presentation within or after 24 h of injury (coded 0,1) and the interaction between the two independent variables. This was included to explore whether presence of a CT head indication affects traumatic CT finding differently in those with delayed presentation. The regression model performance was assessed by the Hosmer and Lemeshow test, which if not significant indicates a good model fit. Given the possibility of reattendances influencing outcomes, a sensitivity analysis was performed using a second model to exclude subjects who reattended.

All analyses were undertaken on SPSS (V.22), a p value of <0.05 was considered to indicate statistical significance.

Research ethics

Collection of these data was undertaken as part of a clinical audit assessing CT head requesting practice against national NICE guidelines. A formal Integrated Research Application System application was made for the use of the data to address the research questions posed in this paper. The relevant Health Research Authority Research Ethics Committee was satisfied that formal ethical approval was not required for the secondary use of audit data for this project.

RESULTS

In the study period, there were 2240 ED CT head requests. Of these requests 676 matched the inclusion criteria for adult head trauma. The remaining 1564 CT head scans were requested for the investigation of: stroke, headaches, seizures, confusion and reduced GCS. Complete ED records were only available for 650 of these requests and therefore 26 CT head scans were not included in analysis. Of the 650 included CT scans, 101 were for patients presenting after 24 h of injury.

Table 1 shows the descriptive summary of the total sample and for those presenting within or after 24 h of injury. The mean age was 53.0 (SD=24.0), which was similar between groups. Overall, 61% were male, and there was a higher proportion of males in those presenting within 24 h compared with

Table 1 Characteristics of patients by time of presentation after injury

Factor	Overall n=650	Within 24 h n=549	After 24 h n=101
Age (mean (SD))	53.0 (24.0)	53.5 (24.2)	50.4 (23.0)
Sex (n (%) male)	394 (60.6%)	346 (63.0%)	48 (47.5%)
Reattendance (n (%))	17 (2.6%)	1 (0.2%)	16 (15.8%)
Initial GCS 13, 14 or 15 (n (%))	620 (95.5%)	521 (94.8%)	99 (98.0%)
Mechanism of injury	Overall	Within 24 h	After 24 h
Fall	405 (62.3%)	355 (64.7%)	50 (49.5%)
Assault	145 (22.3%)	122 (22.2%)	23 (22.8%)
RTC	46 (7.1%)	37 (6.7%)	9 (8.9%)
Sports	13 (2.0%)	7 (1.3%)	6 (5.9%)
Accident (non-specified)	27 (4.2%)	14 (2.6%)	13 (12.9%)
Unknown	14 (2.2%)	14 (2.6%)	0
Presence of risk factor			
Factor	Overall	Within 24 h	After 24 h
Intoxicated at time of injury	325 (36.2%)	227 (41.3%)	8 (7.9%)
Alcohol	229 (35.2%)	222 (40.4%)	7 (6.9%)
Drugs	6 (0.9%)	5 (0.9%)	1 (1.0%)
Dangerous mechanism	82 (12.6%)	77 (14.0%)	5 (5.0%)
Retro-grade amnesia >30 min	101 (15.5%)	100 (18.2%)	1 (1.0%)
Post-traumatic amnesia	282 (43.4%)	266 (48.5%)	16 (15.8%)
LOC	270 (41.5%)	241 (43.9%)	29 (28.7%)
Vomiting	115 (17.7%)	87 (15.8%)	28 (27.7%)
Signs of basal skull fracture	25 (3.8%)	22 (4.0%)	3 (3.0%)
Signs of depressed/open skull fracture	629 (3.2%)	17 (3.1%)	4 (4.0%
Post-traumatic seizure	24 (3.7%)	15 (2.7%)	9 (8.9%)
Focal neurological deficit	34 (5.2%)	23 (4.2%)	11 (10.9%)
Age ≥65	221 (34.0%)	192 (35.0%)	29 (28.7%)

LOC, loss of consciousness; RTC, road traffic collision.

after 24 h. The vast majority of patients presented with minor head injuries and this was similar in both groups. The proportion of patients reattending with an existing injury was only 3%, but there were more reattenders in the delayed presentation group (16% vs 0.2%). The majority of patients had fallen, or been assaulted, with little variation between groups. A higher proportion of patients presenting within 24 h of injury had risk factors associated with the circumstances of injury present, such as loss of consciousness and the presence of a dangerous mechanism of injury. They were also more likely to be recorded as being intoxicated (41.3% vs 7.9%). A higher proportion of patients presenting after 24 h of injury had NICE risk factors present associated with ongoing symptoms including: vomiting, seizures and focal neurological deficits.

Outcomes

Table 2 summarises overall outcomes and as stratified by time of presentation. 8.6% of the CT scans showed a significant traumatic abnormality and the proportion of injuries identified by CT imaging was similar in patients presenting within (8.4%) and after 24 h of injury (9.9%). Overall, 1.2% of patients required neurosurgery and the proportion was slightly lower in patients presenting within 24 h (0.9%) compared with after 24 h of injury (3.0%), although this was not statistically significant (p=0.11). Two patients died, with one death in each time group. There were 56 traumatic CT findings and these results are summarised in table 3 and classified by the major abnormality where there were multiple findings.

Table 2 Outcome measures

Outcome	Overall n=650	Within 24 h n=549	After 24 h n=101	p Value
Traumatic CT finding	56 (8.6%)	46 (8.4%)	10 (9.9%)	0.62
Neurosurgical intervention	8 (1.2%)	5 (0.9%)	3 (3.0%)	0.11
Death	2 (0.3%)	1 (0.2%)	1 (1.0%)	0.29

Presence of a guideline indication

There was no guideline indication present for 13.7% of those presenting within 24 h of injury and 38.6% of those presenting after 24 of injury.

Guideline sensitivity

Table 4 shows the outcome measures and presence of a guideline indication stratified by time of presentation. In those who presented within 24 h, the sensitivity of the guidelines for traumatic intracranial CT findings was 97.8% (95% CI 87.0% to 99.9%) and 100% (95% CI 51.7% to 100%) for neurosurgical outcomes or death. In those who presented after 24 h the sensitivity of the guidelines for traumatic intracranial CT findings was 70% (95% CI 35.4% to 91.9%) and 75% (95% CI 21.9% to 98.8%) for neurosurgical outcomes or death.

Logistic regression analysis

Logistic regression was used to explore traumatic intracranial CT head abnormalities and the relationship between the presence of an indication for a CT head scan and presentation within or after 24 h of injury. In the model, presence of a guideline indication predicted abnormal traumatic findings (p=0.04), while whether presentation occurred within or after 24 h of injury did not (p=0.12). The interaction between NICE indication and time of presentation was not significant (p=0.19). Hence, there was no evidence that a NICE indication affects a traumatic CT finding differently in those presenting within and after 24 h of injury. The results of this analysis are shown in table 5. The Hosmer–Lemeshow goodness of fit test has an associated p value of 1.00.

Table 3 Type of traumatic CT finding

Outcome	Total n=56	Within 24 h n=46	After 24 h n=10
Extradural	6 (10.7%)	5 (10.9%)	1 (10.0%)
Subdural	14 (25.0%)	8 (17.4%)	6 (60.0%)
Subarachnoid	9 (16.1%)	8 (17.4%)	1 (10.0%)
Skull fracture	8 (14.3%)	7 (15.2%)	1 (10.0%)
Contusion	4 (7.1%)	4 (8.7%)	0
Intracerebral haemorrhage	6 (10.7%)	6 (13.0%)	0
Skull fracture+contusion	3 (5.4%)	2 (4.3%)	1 (10.0%)
Skull fracture +intracerebral/ subarachnoid haemorrhage	6 (10.7%)	6 (13.0%)	0

Table 4 Outcome measures by NICE indication and time to presentation after injury

	NICE indication for CT head	No NICE indication for CT head
Patients presenting within 24 h (549)	n=474	n=75
Intracranial injury	45 (9.5%)	1 (1.3%)
Neurosurgical intervention	5 (1.1%)	0
Death	1 (0.2%)	0
Patients presenting after 24 h (101)	n=62	n=39
Intracranial injury	7 (11.3%)	3 (7.7%)
Neurosurgical intervention	2 (3.2%)	1 (2.6%)
Death	1 (1.6%)	0

NICE, National Institute for Health and Care Excellence.

Reattending patients

There were 17 patients that reattended with the same injury. Of these 16/17 had not undergone CT head imaging at their first presentation and underwent cranial CT imaging when they re-presented. One patient underwent CT head imaging at their first presentation and an intracranial haemorrhage was identified. This was managed conservatively and they were discharged. They re-presented due to worsening symptoms and underwent a further CT head scan. This showed no new pathology and therefore was not counted as a positive scan in analysis. Sixteen of the completed scans for reattending patients were completed for presentations after 24 h of injury.

Reattending patients with head injury have previously been identified as a high-risk group.[15] The 17 subjects reattendances were excluded from the analysis and sensitivity analyses were performed to quantify the effect of reattendance on model performance. The proportion of injury for patients presenting within and after 24 h remained similar: 8.4% and 7.1%, respectively. The sensitivity of the guidelines for patients presenting within 24 h is unaltered by the exclusion or reattenders. For patients presenting after 24 h the sensitivity for intracranial injury decreases slightly to 66.7% (24.1% to 94% 95% CI). Significantly, the only patient with a neurosurgical outcome where there was no guideline indication for a CT head scan was a reattending patient.

With use of the same set of predictor variables, the exclusion of the 17 re-attendances did not alter the model. The presence of a guideline indication for a CT head remained statistically significant as a predictor of intracranial injury (p=0.046, OR 7.66, 95% CI 1.04 to 56.42) and whether presentation occurred within or after 24 h of injury did not (p=0.231, OR 4.42, 95% CI 0.39 to 50.53). The interaction between the presence of NICE indication and time of presentation remained not significant (p=0.217).

Table 5 Logistic regression analysis

Factor	Sig	OR traumatic CT finding
NICE guideline indication present	p=0.04	7.76 (95% CI 1.05 to 57.18)
Presentation after 24 h	p=0.12	6.17 (95% CI 0.62 to 61.38)
NICE guideline indication×presentation after 24 h	p=0.19	0.20 (95% CI 0.017 to 2.28)

NICE, National Institute for Health and Care Excellence.

DISCUSSION

This study has identified patients with head injury presenting after 24 h of injury as being a clinically significant population that accounted for 15.5% of cranial CT scans for adult head trauma. A similar rate of CT-identified traumatic brain injury was detected in this group as in patients presenting earlier. The presence of a CCHR-based CT head indication was found to be predictive of significant traumatic pathology irrespective of time of presentation. However, in patients presenting after 24 h the strict application of the guideline would have failed to identify a higher proportion of significant injuries including an injury that required neurosurgery.

This is a small study with small numbers of patients presenting after 24 h, and with traumatic CT findings. There are also other potential limitations. Patients presenting after 24 h were found to be significantly less likely to have NICE indications pertaining to the circumstances of injury such as loss of consciousness and the presence of a dangerous mechanism of injury. This is likely due to patients with dangerous mechanisms of injury or immediate symptoms presenting earlier after their injuries. However, it could reflect recall bias where patients presenting in a delayed manner are less likely to remember these factors and therefore be correctly assessed. This would undermine the validity of conclusions drawn about the difference in the application and sensitivity of the NICE guidelines.

This study has only evaluated a cohort of patients with head injury that have undergone CT imaging and therefore no estimate of the specificity of the guidelines can be made. The estimated prevalence of intracranial injury is only for this patient group and will be higher than the prevalence of such injuries in all patients with head injury. Patients that did not have CT scans but had serious intracranial pathology that failed to represent to the HRI within the 6-month period may also have been missed. Patients that were discharged and died as a result of their injuries would also have been missed unless their hospital case notes included details of this. A small number of incomplete records meant that some eligible patients were excluded from analysis. This is a potential source of selection bias, although the low number of such patients makes this risk small. Finally, as this study uses a retrospective case note review for data extraction it is limited by how accurately and completely information was recorded.

To the knowledge of the authors, this is the first study undertaken that directly compares a cohort of delayed presentation head-injury patients to a non-delayed comparator population. It has identified patients with head injury presenting >24 h following an injury as a significant clinical population. The overall prevalence of significant injuries was found to be 8.6%, which is comparable with that reported in other studies.[4 16 17] The prevalence of traumatic intracranial pathology and neurosurgery was comparable in the two groups. This would suggest that patients presenting after 24 h are not a lower-risk group.

The strict application of current head-injury decision rules to patients presenting after 24 h of injury may risk missing a high proportion of clinically significant injuries (30% in this cohort). Tellingly, clinicians appear to be aware of this and were found to be significantly more likely to request a CT head scan when no NICE indication was present in this group.

CONCLUSION

Further research is required to identify the risk factors that predict significant intracranial injuries in patients presenting after 24 h of injury. Clinicians should be aware that this group has a distinct risk profile and that a lack of a guideline indication for a CT scan does not rule out significant intracranial injuries in this group.

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Contributors Carl Marincowitz formulated the idea for the study and conducted the majority of data collection and analysis. William Townend and Victoria Allgar both had supervisory roles. Victoria Allgar contributed heavily to the statistical analysis and William Townend provided in depth clinical knowledge of the subject area. The final paper was produced as a collaborative effort between the three authors.

Competing interests None declared.

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