Can we abolish skull x-rays for head injury?

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Abstract

Objectives:
To assess the effect of a change in skull x-ray policy on the rate of admission, CT imaging, radiation dose per head injury and detection of intracranial injuries. To compare the characteristics of patients meeting criteria for CT scanning with a group matched for age, triage category and sex. To compare the characteristics of patients with a normal CT scan to those with an abnormal CT scan.

Design:
Retrospective cohort study.

Setting:
UK paediatric teaching hospital emergency department (ED).

Patients:
1535 patients aged between 1 and 14 years of age presenting to the ED between August 1st 1998 and July 31st 1999, and 1867 patients aged between 1 and 14 years of age presenting between August 1st 2002 and July 31st 2003 with a head injury.

Intervention:
Hospital notes and computer systems were analysed and data were collected on all patients presenting with a head injury.

Results:
The abolition of skull x-rays in children over 1 year of age prevented about 400 normal skull x-rays being performed in period 2. The percentage of children undergoing CT rose from 1.0% to 2.1% with no change in the positive CT pick up rate (25.6% compared to 25.0%). There was no significant change in admission rate (10.9% compared to 10.1%), and a slight decrease in the radiation dose per head injury (0.042mSv compared to 0.045 mSv).

Conclusions:
Skull x-rays can be successfully abandoned in those aged 1 to 14 without any significant increase in admission rate, radiation dose per head injury, or missed intracranial injury rate. We suggest that routine skull x-rays have no place in the paediatric ED for those children aged 1 year and over. Mechanism of injury, history and a reduced GCS are probably the most important indicators of significant head injury in children.

Key words:
Head injury, skull x-ray, CT scan.
Introduction

One million patients are treated annually in UK emergency departments (ED) for head injury \[1\]. Children under the age of 16 years make up one half of these \[2\]. Forty-five percent of these childhood injuries occur in those under 5 years of age \[3\], most being minor. There are 4011 ED attendances, 400 admissions and 5.3 deaths per 100,000 children per year \[4\]. Head injuries contribute to 10% of childhood hospital admissions (about 50,000 per year in the UK) \[5\], and they are one of the leading causes of developed world trauma deaths accounting for 15% of fatalities between the ages of 1 and 15 \[6\].

Present paediatric guidelines differ in their emphasis on skull x-ray usage. National Institute for Clinical Effectiveness (NICE) guidelines suggest skull x-rays have a role combined with high quality in-patient observation where Computed Tomography (CT) scanning is unavailable \[7\]. Scottish Intercollegiate Guideline Network (SIGN) guidelines place more emphasis on skull x-rays where there are risk factors for fracture or intracranial injury, although they acknowledge that skull fractures in children are less commonly associated with intracranial injury, and therefore their detection is less helpful than in the adult population \[8\]. Head injury guidelines from North America omit skull x-rays, and CT is the predominant scanning modality. In the US, up to 60% of head injured patients undergo CT with a resultant low positive rate of between 5 and 10%. Less than 30% of those with intracranial abnormalities go on to require neurosurgical intervention \[9\].

Between 23% and 50% of skull fractures are missed by junior doctors \[10\], and there are many false positive diagnoses. The presence of a skull fracture has previously been suggested to hugely increase the risk of an intracranial injury \[11,12\]. However in children, severe intracranial injury can occur in the absence of a skull fracture \[10\].

Our ED head injury policy was revised in 1999 to reduce the emphasis on skull x-rays, and to restrict the ordering of them to those aged under 1 year (infants) whom we believe are a special population. They are extremely difficult to assess for symptoms and signs of head injury and they suffer a much higher incidence of non-accidental injury (NAI). This study is therefore restricted to children between the ages of 1 and 14. The revision of our head injury policy gives us a unique opportunity to assess the impact of the abolition of skull x-rays on the management of paediatric head injured patients.

There are three main aims to our study: firstly, to assess the effect of a change in skull x-ray policy on the rate of admission, CT imaging, radiation dose per head injury and detection of intracranial injuries in a paediatric ED; secondly, to compare the characteristics of patients meeting criteria for CT scanning with a group matched for age, triage category and sex; and finally, to compare the characteristics of patients having a normal CT scan with those having an abnormal CT scan.

Design

This study is a retrospective cohort study conducted in the dedicated paediatric ED of a UK teaching hospital. The departmental head injury policy was revised in 1999 to restrict the ordering of skull x-rays to those aged under 1 year (Table 1).

For the initial part of the study, the ED computers were interrogated and notes were retrieved for all patients aged over 1 year and under 14 years, presenting within two periods. Period 1 was between August 1st 1998 and July 31st 1999, and period 2 was between August 1st 2002 and July 31st 2003. The first period was chosen as it represents the last full year before the revision of the departmental head injury policy, and the latter period as it represents the most recent comparable full year since the introduction of the revised head injury policy. The radiology department computer was also interrogated, and a list of all CT scans and skull x-rays performed during these periods was compiled. Total radiation doses were calculated for each period using typical radiation doses \[13\]. The techniques used for skull x-rays and CT scans during both periods
were identical. Details of the patient’s age, triage category and subsequent destination were also available.

For the second part of the study, all patients who underwent a CT scan during period 2 were compared to an equal number of patients matched for age, triage category and sex who also presented during period 2, and who did not undergo a CT scan. The purpose of this was to define characteristics of patients who were thought to be at high risk of a significant head injury and therefore required CT scanning. Hospital notes were retrieved for all patients in both groups, and details of their injury, treatment and subsequent course were all entered on a specially designed proforma. Records were scanned to identify children who returned for unexpected review, or those who deteriorated or developed complications after initial discharge. As our hospital is the only admitting paediatric hospital in the area, all children in this category would have re-attended here or would have been admitted here.

Finally, patients having a normal CT scan were compared to patients having an abnormal CT scan. Positive and Negative predictive values were calculated to determine the likelihood of an abnormal CT scan in the presence of each factor, and the likelihood of a normal CT scan in the absence of each factor. These values were calculated in order to determine the usefulness of each factor at predicting significant head injury. Comparison with the second part of the study will determine which factors lead to a CT scan being performed, but which are poorly associated with an abnormal scan.

All information collected was analysed using Microsoft Excel. The Fisher exact test was used to compare categorical data and the Mann-Whitney U-test was used to compare non-parametric numerical data.

Results

During period 1, 1535 patients over 1 year of age and less than 14 years of age presented to the ED, compared to 1867 patients in this age range during period 2 (Table 2).

Figure 1 shows the distribution of head injuries by age during both time periods. The male:female ratio in period 1 was 64%: 36% and the median age was 5.02 years (interquartile range 2.49 - 8.38). This compared to a male: female ratio of 67%: 33% during period 2 (p=0.42) with a median age of 4.87 years (IQR 2.53 - 8.56 years, p=0.62).

During period 1 there were 44 patients (2.9% of the total head injuries between 1 and 14 years of age) allocated to triage category 1 or 2 (very serious and urgent categories), and 1491 patients (97.1%) allocated to triage category 3 or 4 (less severe and less urgent). During period 2, equivalent figures were 50 patients (2.7%) allocated to triage category 1 or 2, and 1817 patients (97.3%) allocated to triage category 3 or 4 (p=0.75).

340 patients (22.1%) underwent a skull x-ray in period 1 compared to none in period 2. Three hundred and twenty-eight (96.5%) of these x-rays during period 1 were normal. There were 12 (3.5%) x-rays which were abnormal. Three of these were suspicious of a skull fracture and these patients went on to have a normal CT scan (receiving a dose of radiation twice). Of the 9 that showed a definite skull fracture, 2 went on to have a CT scan. One CT scan showed an 8mm right frontal depressed skull fracture with a small underlying contusion, and one an isolated left parietal bone fracture with no intracranial injury. There were 2 other significant (i.e. patients with an abnormal brain CT) head injuries during period one (Table 3). Both of these injuries occurred in patients undergoing a CT scan as initial imaging modality.

In total, 16 (1.0%) patients underwent a CT scan during period 1 resulting in 4 abnormal scans (25.0% positive CT rate). 3 scans showed intracranial injury, none of which required neurosurgical intervention. This compares to 39 patients (2.1%) undergoing CT scanning during period 2 (p=0.02). Of these 39 CT scans, 10 scans (25.6% of all period 2 CT scans) were abnormal. There were 7 patients with underlying intracranial injury (p=0.53), and 2 patients who
required neurosurgical intervention ($p=0.30$) (Table 3). No patients received an ultrasound scan or a MRI scan in the acute setting during either period, and all patients survived to hospital discharge. 154 patients (10.1%) were admitted during period 1 compared to 203 (10.9%) patients during period 2 ($p=0.43$). Of those admitted during period 1, 5 patients (3.2%) went to the intensive care or high dependency unit and 149 patients (96.1%) went to the ward. During the second period, 13 patients (6.0%) went to the intensive care or high dependency unit and 190 patients (93.6%) went to the ward ($p=0.23$).

The total radiation dose for period 1 was 69.65 mSv compared to a total dose of 78.0 mSv for period 2. Radiation dose per head injury for period 1 was 0.045 mSv compared to 0.042 mSv for period 2. Statistical analysis of this data is not possible due to the pattern of its spread. Figures 2a and 2b summarize the flow of patients through their investigations and management. There were no adverse sequelae in either group attributable to either policy decisions.

For the second part of the study, the 39 patients who underwent a CT scan during period 2 were compared to 39 patients matched for age, triage category and sex who presented during period 2, and who did not undergo a CT scan (Table 4). Patients undergoing a CT scan had a higher proportion of falls from a height greater than 1 meter and road traffic accidents, and a lower proportion of falls less than 1 meter. They also had a higher proportion of all types of neurological symptoms. Patients undergoing CT were less likely to have a scalp laceration. However there was little difference with other injury type. The small number of patients in each category precludes further useful statistical analysis of this data.

Finally, patients with a normal CT scan in the period 2002-03 were compared with those with an abnormal CT scan in the same period (Table 5). Of the 10 patients who had an abnormal CT scan, the commonest injury mechanisms were falling more than 1 meter (3 patients) and being involved in a road traffic accident (6 patients). Of the 29 patients having a normal CT scan, the commonest injury mechanisms were a fall of less than 1 meter (9 patients) and a direct blow to the head (8 patients). Drowsiness (6 patients) and loss of consciousness (5 patients) were the commonest symptoms in the 10 patients having an abnormal scan. All 8 patients undergoing CT because of persistent vomiting had a normal scan.

Injuries found on examination were not predictive of an abnormal CT scan, and all patients who had an abnormal scan received their scan within 1 hour. Again, the small number of patients precludes further statistical analysis.

**Discussion**

The publication of guidelines by NICE and SIGN has signalled that a new approach to the management of head injury is needed. The publication by Lloyd et al has indicated that too many skull x-rays are being requested, with a significant unnecessary exposure to radiation by a large number of children [10]. Any change in policy however must ensure that clinical safety is not being compromised. We introduced a change in radiographic policy for head trauma after a careful examination of the literature, and ensured that child safety would be ensured by liberalising the option to admit, with a more liberal policy on CT request. The outcome from this change in policy is unique in that this is the first paper to evaluate such a policy. In addition it anticipates the approach suggested by NICE and provides a framework within which other departments might alter policy.

Our results indicate that the abolition of skull x-rays in children aged 1 year and over prevented about 400 normal skull x-rays being performed in period 2 with no detriment to any child in terms of missed injury. The percentage of children undergoing CT rose from 1.0% to 2.1% with no change in the positive CT pick up rate (25.6% in period 2 compared to 25.0% in period 1). This compares favourably with figures from the American literature of 10% [9]. There was no significant change in admission rate (10.9% compared to 10.1%). However there was a slight non-significant increase in the percentage of patients being admitted to HDU and ITU (6.0% compared
to 3.2%). This is due to the greater number of significant head injuries that occurred during the second period.

There was a slight decrease in the radiation dose per head injury presentation (0.042mSv compared to 0.045 mSv). Whilst there was a reduction in the radiation dose, there were a few patients in period 2 who received a much higher dose of radiation (those who underwent a CT scan), and a huge number who received no radiation. This drop in radiation dose would probably have been much more impressive if it was not for the slight increase in injury severity seen during period 2.

Comparison of the patients with a normal CT with those with an abnormal CT suggests that the mechanism of injury is an important predictor of head injury severity. An abnormal CT scan was more likely in a patient who had sustained a fall greater than 1 meter or who had been involved in a road traffic accident. Falls less than 1 meter and direct blows to the head were both more likely to be associated with a normal CT scan. The exception to this may be injury caused by a blow to the head with a golf club, a relatively common childhood leisure pursuit in Scotland compared to anywhere else. In our series there were no serious injuries from this mechanism. This has been shown in the past to be a risk factor for significant head injury [14].

Patients who had an abnormal scan were more likely to have had a history of loss of consciousness or drowsiness. No patients with a history of vomiting had an abnormal scan. This has been shown previously to be a poor diagnostic sign of significant head injury [15]. Neurological observations were a more reliable predictor of intracranial injury than documented superficial injuries. This may be due to a failure to document superficial injuries accurately when the patient has neurological signs that are an immediate indicator for a CT scan, and highlights a limitation of retrospective data collection.

All patients who ended up having an abnormal brain CT were scanned immediately. This suggests that although it is well documented that intracranial injury can present some time after the initial injury, clinical suspicion is an extremely good predictor of head injury. This bears out the work of Sainsbury and Sibert [16]. They determined in a Welsh population that all significant head injuries in children declared themselves as such within 6 hours of injury. 10 out of 18 (55.6%) CT scans that were arranged within one hour of the patient attending the ED were positive. None of these immediate scans were in patients presenting late after sustaining their injury.

Finally, 9 out of 14 (64%) patients undergoing CT scanning due to a reduced Glasgow Coma Score (GCS) had an abnormal scan, whilst all patients with a CT indication of vomiting or persistent headache had a normal scan.

**Conclusion**

This study demonstrates that skull x-rays can be successfully abandoned in those aged 1 to 14 without any significant increase in admission rate, radiation dose per head injury, or missed intracranial injury rate. We suggest that routine skull x-rays have no place in the paediatric ED for those children aged 1 year and over. Mechanism of head injury (falls >1 meter and road traffic accidents), a history of drowsiness or loss of consciousness, and a reduced Glasgow Coma Score are probably the most important indicators of serious head injury in children.
Table and Figure Legends

**Table 1** 1998-99 and 2002-03 guidelines for radiological imaging in head injuries (RHSCE Emergency Department’s head injury policy).

**Table 2** Comparison between the two study periods, one before and one after the abolition of skull x-rays.

**Table 3** Details of patients sustaining significant head injuries during both study periods.

**Table 4** Comparison between 39 patients undergoing CT scanning in 2002-03 and 39 age, sex and triage category matched patients presenting during the same period.

**Table 5** Comparison between patients having a normal CT scan and patients having an abnormal CT scan in 2002-03.

**Figure 1** Distribution of head injuries by age.

**Figure 2a** Patient flow chart 1998-9.

**Figure 2b** Patient flow chart 2002-3.

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We thank Rik Smith at the Scottish Trauma Audit Group for statistical advice, and the radiographers in the x-ray department at RHSCE for help with retrieval of CT and x-ray data.

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References

16 Sainsbury CP, Sibert JR. How long do we need to observe head injuries in hospital? *Archives of Disease in Childhood*. Sep 1984; 59(9): 856-9.
### 1998-99 Radiological guidelines

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<thead>
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<td>Amnesia.</td>
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<td>Persisting headache, vomiting or lethargy.</td>
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<td>Coagulation or bleeding diathesis (also needs discussion with haematology).</td>
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<td>Seizure (focal or prolonged).</td>
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<tr>
<td>Signs of base of skull fracture.</td>
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<tr>
<td>? Penetrating injury.</td>
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<tr>
<td>? Depressed fracture.</td>
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### 2002-03 Radiological guidelines

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<td>Age less than 1 year and suspicious history for NAI.</td>
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<tr>
<th><strong>Admission for observation and/or CT</strong></th>
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<td>Persisting headache, vomiting or lethargy.</td>
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<td>Coagulation or bleeding diathesis (also needs discussion with haematology).</td>
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<td>Focal neurological signs.</td>
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<tr>
<td>Seizure (focal or prolonged).</td>
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<tr>
<td>Signs of base of skull fracture.</td>
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<td>? Depressed fracture.</td>
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Table 2

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<th>1998-99</th>
<th>2002-03</th>
<th>P=</th>
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<tr>
<td>Head injuries &gt;1 and &lt;14 years</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male : Female ratio</td>
<td>975 : 560</td>
<td>1248 : 619</td>
<td>0.42²</td>
</tr>
<tr>
<td>Median age (years) (IQR)</td>
<td>5.02 (2.49-8.38)</td>
<td>4.87 (2.53-8.56)</td>
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<td>Urgent triage (1 or 2)</td>
<td>44 (2.9%)</td>
<td>50 (2.7%)</td>
<td>0.75²</td>
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<tr>
<td>Delayed triage (3 or 4)</td>
<td>1491 (97.1%)</td>
<td>1817 (97.3%)</td>
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</tr>
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<td>Skull x-rays</td>
<td>340 (22.1%)</td>
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<td></td>
</tr>
<tr>
<td>Number of 1-view x-rays</td>
<td>7 (2.1%)</td>
<td>0</td>
<td></td>
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<tr>
<td>Number of 2-view x-rays</td>
<td>233 (68.5%)</td>
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<tr>
<td>Number of 3-view x-rays</td>
<td>100 (29.4%)</td>
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<tr>
<td>Normal skull x-rays</td>
<td>328 (96.5%)</td>
<td>0</td>
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<td>Abnormal skull x-rays</td>
<td>12 (3.5%)</td>
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<tr>
<td>SXR total radiation dose</td>
<td>37.65 mSv</td>
<td>0 mSv</td>
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<tr>
<td>CT scans</td>
<td>16 (1.0%)</td>
<td>39 (2.1%)</td>
<td>0.02²</td>
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<tr>
<td>Abnormal CT scans</td>
<td>4 (25.0%)</td>
<td>10 (25.6%)</td>
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<td>CT total radiation dose</td>
<td>32.0 mSv</td>
<td>78.0 mSv</td>
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<tr>
<td>Discharged</td>
<td>1381 (89.9%)</td>
<td>1664 (89.1%)</td>
<td>0.43²</td>
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<tr>
<td>Admitted</td>
<td>154 (10.1%)</td>
<td>203 (10.9%)</td>
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<td>ITU / HDU</td>
<td>5 (3.2%)</td>
<td>13 (6.0%)</td>
<td>0.23²</td>
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<td>Ward</td>
<td>149 (96.1%)</td>
<td>190 (93.6%)</td>
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<td>Total radiation dosage</td>
<td>69.65 mSv</td>
<td>78.0 mSv</td>
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<td>Radiation dosage / head injury</td>
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<tr>
<td>Intracranial injuries</td>
<td>3 (0.20%)</td>
<td>7 (0.37%)</td>
<td>0.53²</td>
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<tr>
<td>Neurosurgical intervention</td>
<td>0 (0%)</td>
<td>2 (0.10%)</td>
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¹= Mann-Whitney U-test.
²= Fisher exact test.
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<thead>
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<th>Year</th>
<th>Case 1</th>
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<th>Case 3</th>
<th>Case 4</th>
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<td>1998-99</td>
<td>Extensive middle cranial fossa fractures with some small areas of contusion.</td>
<td>Comminuted, depressed right parietal fracture with underlying contusion.</td>
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<td></td>
<td>Widespread cerebral contusions.</td>
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<td>Widespread cerebral contusions.</td>
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<td>Right frontal lobe subdural haematoma with contusions.</td>
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<td>Right frontal lobe subdural haematoma with contusions.</td>
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<td>n</td>
<td>%</td>
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<td>2</td>
<td>5%</td>
<td>3</td>
<td>8%</td>
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<tr>
<td>Fall &gt; 1 meter</td>
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<td>7</td>
<td>18%</td>
<td>5</td>
<td>13%</td>
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<td>Fall &lt; 1 meter</td>
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<td>10</td>
<td>26%</td>
<td>19</td>
<td>49%</td>
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<td>Fall down stairs</td>
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<td>2</td>
<td>5%</td>
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<td>10</td>
<td>26%</td>
<td>1</td>
<td>3%</td>
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<td>Direct blow to head</td>
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<td>8</td>
<td>21%</td>
<td>11</td>
<td>28%</td>
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<td>9</td>
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Table 5

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<th>Positive Predictive Value</th>
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Total head injuries 1714

Head injuries ≥1 year of age 1535

Skull x-ray?

Y 340

?# 3

no # 328

N 1195

# 9

CT?

Y 2

N 7

N 0

ABN 2

ADM?

Y 1

N 3

N 1

ABN 1

ADM?

Y 70

N 257

ADM?

Y 10

N 1

ADM?

Y 2

N 65

N 1118

ADM?

Y 1

N 1

ADM?

Y 2

N 0

ADM?

Y 1

N 1

ADM?

Y 2

N 0

ADM?

Y 2

N 0

ADM?

Y 2

N 0

ADM?

Y 1

N 1

ADM?

Y 2

N 0

ADM?

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