Clinical manifestations that predict abnormal brain computed tomography (CT) in children with minor head injury

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ABSTRACT

Background: Computed tomography (CT) used in pediatric pediatrics brain injury (TBI) to ascertain neurological manifestations. Nevertheless, this practice is associated with adverse effects. Reports in the literature suggest incidents of morbidity and mortality in children due to exposure to radiation. Hence, it is found imperative to search for a reliable alternative. Objectives: The aim of this study is to find a reliable clinical alternative to detect an intracranial injury without resorting to the CT. Materials and Methods: Retrospective cross-sectional study was undertaken in patients (1-14 years) with blunt head injury and having a Glasgow Coma Scale (GCS) of 13-15 who had CT performed on them. Using statistical analysis, the correlation between clinical examination and positive CT manifestation is analyzed for different age-groups and various mechanisms of injury. Results: No statistically significant association between parameteres such as Loss of Consciousness, ‘fall’ as mechanism of injury, motor vehicle accidents (MVA), more than two discrete episodes of vomiting and the CT finding of intracranial injury could be noted. Analyzed data have led to believe that GCS of 13 at presentation is the only important clinical predictor of intracranial injury. Conclusion: Retrospective data, small sample size and limited number of factors for assessing clinical manifestation might present constraints on the predictive rule that was derived from this review. Such limitations notwithstanding, the decision to determine which patients should undergo neuroimaging is encouraged to be based on clinical judgments. Further analysis with higher sample sizes may be required to authenticate and validate findings.

Key Words: CATCH rule, contusion, Chi square test, Glasgow coma scale, hematoma

INTRODUCTION

Accidents in childhood range from minor injuries that do not require hospital visits to more serious injuries that require medical attention. Among those that require medical attention, head injuries account for the majority of injuries in Saudi Arabia.[1]

Most head traumas cause minor head injuries (MHI) which rarely require neurosurgical intervention or lead to long term sequelae.[2] Furthermore, pediatric patients with MHI have a low incidence of occurrence of delayed neurological manifestation.[3]

American Academy of Pediatrics defines MHI in otherwise healthy children more than 2 years of age as normal mental status at initial examination with no focal neurologic signs and no clinical signs of skull fracture.[4] GCS between 13-15 post blunt head trauma is being used in literature as a definition of MHI in children more than 2 years of age.[5]

Many of the neurological manifestations are evident soon after head trauma. MHI are associated with brief symptoms like vomiting, concised loss of consciousness after the event and are rarely associated with neurological manifestation that require...
intervention. Having said that, some life-threatening injuries can present initially as MHT adding to the challenges in diagnosis and evaluation of such injuries. This fact has contributed to increased use of Brain Computed Tomography (Brain CT) in children with MHI although the diagnostic yield has remained low. It has been reported that only 5% of children with MHI have had abnormal Brain CT finding and less than one percent of them have required neurosurgical intervention. Brain CT is considered an effective diagnostic modality to detect rare but clinically significant intracranial abnormalities in children suffering from MHI. In contrast, the increased use of CT in MHI carries the risk of sedation, public health cost burden, and potentially harmful effect of exposure to ionizing radiations. The lifetime estimated risk of cancer from CT is substantially higher in children due to longer subsequent lifetime and organs’ sensitivity to radiation.

Currently data on evidence based recommendations for evaluation of children with MHI and use of Brain CT vary widely among several studies. To date no single clinical feature is considered reliable to detect an intracranial injury. A cohort study that evaluated children with MHI concluded that the absence of abnormal mental status and clinical signs of skull fracture with no history of vomiting and headache carries a low risk for any abnormalities. A larger multicenter cohort study involving 42,412 children younger than 18 years of age with MHI and Glasgow Comma Scale (GCS) 14-15 with the aim of validating the prediction rules for low risk children for clinically important TBI reported that clinically important TBI occurred in 0.9% of cases and only 0.1% underwent neurosurgery. Children younger than 2 years of age who have a normal mental status, no scalp hematoma, no loss of consciousness or brief loss of consciousness, no sign of skull fracture and behaving normally had a negative predictive value of 100% (95% CI 99.7-100) and sensitivity of 100% (95% CI 86.3-100). In children older than 2 years, the clinical prediction rule had a negative predictive value of 99.95% and sensitivity of 96.8% provided the patient had a normal mental status, no loss of consciousness, no vomiting, no sign of basal skull fracture and no severe headache. The CATCH rule developed by the Canadian Assessment of Tomography for Childhood Injury has identified a medium risk for brain injury criteria. The medium risk criteria consists of any sign of basal skull fracture, large scalp hematoma and a dangerous mechanism of injury with sensitivity of 98%. The wide variation of the clinical prediction rules in literature, though with a high reported sensitivity needs further validation and should not preclude the clinical judgment that suggests which patient with a minor head injury needs a brain CT. An observational study that compared the decision rule with clinician judgment for identifying children at risk of traumatic brain, found higher sensitivity for decision rule compared to better specificity to the clinical judgment. The application of decision rule would have resulted in 24.7% less CT scans.

The Arab Gulf region has research paucity on the prevalence of clinically important TBIs in children with minor head trauma. Having said that, a significant number of pediatric population in the Gulf area is subjected to high number of moderate to severe trauma and high rate of serious road traffic accidents. Convulsion in minor head injury predicts positive CT finding in 80% of cases as has been reported in a prospective study done in Qatar that involved pediatrics and adults patients.

The aim of this study is to investigate the clinical manifestations that predict abnormal brain CT in children with minor head injury and to develop an accurate and reliable clinical decision rule that helps decide when to use brain CT as a diagnostic modality.

MATERIALS AND METHODS

Type of study and Setting
Retrospective cross-sectional design was employed for the study. The work was carried out at the Emergency Medicine Department of at King Abdulaziz Medical City and Colleges of Medicine and Public Health and Health Informatics, King Saud Bin Abdulaziz University for Health Sciences, Riyadh, Saudi Arabia.

Subjects, inclusion and exclusion criteria
The target population consisted of patients who presented to the Emergency Department, (ED) with blunt head injury in the year 2011 and had brain CT ordered by ED physician. The inclusion criteria was: Age between 1-14 years, GCS of 13-15, blunt head injury, healthy (with no pre-existing medical condition that predisposes the patient for a tendency to bleed) and presentation within 24 hours post injury at ED. The exclusion criteria was: Penetrating head injury, local facial signs post trauma, signs of basal skull fracture, co-morbidities that predispose to bleeding tendency, multiple major traumas, prolonged amnesia and LOC (prolonged amnesia and loss of consciousness for more than 5 minutes), active seizure on arrival to ED and GCS score less than 13.

Ethical consideration
As the research involve interventions on human subjects, the study was subjected to approval from Ethics committee (Institutional Review Board), King Abdullah International Medical Research Center. Patients confidentiality was strictly observed throughout the study by using patients anonymous unique serial number for each subject and restricting data access to the investigators.

Data extraction and the outcome
The data was extracted from the radiology department database between the periods January 1, 2011 to December 31, 2011. The data was extracted from two pediatricians who independently evaluated the cases and compiled on an Excel spread sheet with all the variables. The ED triage, nursing and physician electronic notes were used to collect the data. The variables were coded into binary outcomes. The primary outcome measure was the
extent of brain injury as determined by CT. The outcome is specified as ‘significantly abnormal brain CT’ if there is an intracranial pathology as reported by the radiology consultant which include the following: Epidural and subdural hematoma, intracranial diffuse hematoma, cerebral edema, depressed skull fracture and cerebral contusion. Simple linear skull fracture and scalp soft tissue injuries were not considered to be significant and were not included as an outcome.[15,16] Secondary outcome is specified as the requirement of neurosurgical interventions post minor head injury and the consequent need for hospitalization.

Statistical analysis
The statistical analysis was carried out using the statistical product and service solutions (SPSS) version 18. $P$ value of less than 0.05 was considered statistically significant. Descriptive statistical parameters were calculated for all variables across the cohort. Numbers, tables and percentages were used to describe categorical variables. Mean and standard deviation were used for continuous variables. Univariate analysis was carried out to test the association between the primary outcome and the predictor in the study using Chi square test. Logical regression was used to predict abnormal brain CT.

RESULTS
A total 289 out of 580 cases met the inclusion criteria. The mean age group was 6 years with standard deviation ±4 [Table 1]. 71.3% of evaluated cases were males. Fall was the most common mechanism of injury, representing 152 out of 289, which account for 52.6% [Figure 1]. Fall form a Short distance was reported in 131 cases (45.3%) while fall from more than 1.5 meters or more than five stairs was reported in 21 cases (7.3%). ‘Motor Vehicle Accident’ was the second most common mechanism of injury and was reported in 65 cases (22.5%) followed by direct impact on head in 42 cases (14.5%). Pedestrians accounted for 24 cases (8.3%) and physical assault was reported in 5 cases (1.7%). Analyzing the mechanism of injury in relation to age revealed that 63% were children 3 years and younger and the majority occurrences were ‘involved falls form a short distance’. In children aged 10 years and older, motor vehicle accident (MVA) was the most common cause of injury.

Abnormal brain CT finding post minor injury accounted for 4.8%. The most common abnormal brain CT finding was ‘complicated skull fracture’ followed by subdural hematomas [Table 2]. None of the patients with abnormal brain CT underwent neurosurgical interventions; however, neurosurgical consultation was required in four patients (1.4%). Abnormal brain CT was found to be more in males (6.3%) compared to female (1.2%). Males were found to be at five times more risk to have abnormal brain CT compared to females with odds ratio of 5.5 and 95% CI (0.71-42.9). CI crossed the null hypothesis value indicating no statistical significance.

History of loss of consciousness and vomiting was the most common complaint and accounted for 30%. Headache as a

| Table 1: Demographics & mechanism of injury |
|-------------------------------------------|
| Variable              | Values |
| Age (Means±SD), Years | 6.06±4.0 |
| Age ≤3 n (%)          | 103 (35.6) |
| Age 4-5 n (%)         | 45 (15.6) |
| Age 6-9 n (%)         | 72 (24.9) |
| Age ≥10 n (%)         | 69 (23.9) |
| Sex                   |         |
| Male n (%)            | 206 (71.3) |
| Female n (%)          | 83 (28.7) |
| Fall N (%)            | 152 (52.6) |
| Short Fall n (%)      | 131 (45.3) |
| Long Distance Fall n (%) | 22 (7.3) |
| MVA* n (%)            | 65 (22.5) |
| Pedestrian n (%)      | 24 (8.3) |
| Direct Impact n (%)   | 42 (14.5) |
| Physical Assault n (%) | 5 (1.7) |
| Child Physical Abuse n (%) | 1 (0.3) |

*MVA: Motor Vehicle Accident

| Table 2: Outcome of the brain CT |
|----------------------------------|
| Brain CT outcome                |         |
| Normal n (%)                    | 275 (95.2) |
| Abnormal n (%)                  | 14 (4.8) |
| Neurosurgery                    |         |
| Consultation n (%)              | 4 (1.4) |
| Intervention n (%)              | 0 (0)   |
| Hospital admission              |         |
| Yes n (%)                       | 0 (0)   |
| No n (%)                        | 289 (100) |
| Sedation given before ct        |         |
| Yes n (%)                       | 23 (8)  |
| No n (%)                        | 266 (92) |
| CT brain findings               |         |
| cerebral edema n (%)            | 1 (0.35) |
| basal skull fracture n (%)      | 1 (0.35) |
| depressed skull fracture n (%)  | 1 (0.35) |
| subdural hematoma n (%)         | 4 (1.4)  |
| complicated skull fracture n (%)| 6 (2)   |
| intracranial hemorrhage n (%)   | 1 (0.35) |
complaint post head injury was reported in 15% cases. History of seizure and amnesia were rare complaints and accounted for 4.2% and 1% respectively [Table 3].

Children with fall as mechanism of injury with abnormal brain CT was reported in 7 patients (4.6%) with odds ratio of 0.9 (95% CI 0.31-2.624). Abnormal brain CT was reported in 3 patients who had a fall over a long distance (14.3%). The odds of having abnormal brain CT from long distance fall was three however, P-value was not statistically significant (P value = 0.12).

Motor vehicle accidents were not statistically associated with abnormal brain CT. Abnormal brain CT was reported in 2 cases (3.1%) with odds ratio of 0.57 (95% CI 0.12-2.6) where 95% CI has crossed the null hypothesis value.

Pedestrians were not associated with increased risk of abnormal brain CT as an outcome. One case (4.2%) was reported to have an abnormal brain CT with odds ratio of 0.843 (95% CI 0.11-6.7) and P value 0.87.

‘Direct impact’ as the cause was found to be associated with twice the risk for having an abnormal brain CT with odds ratio of 2.5; however, the 95% CI had crossed the null hypothesis value (0.75-8.35) with the P value of 0.13. GCS of 13 at presentation to the ED was associated with five times the risk of abnormal brain CT with odds ratio 5.2 and 95% CI (1.1-27), and P value 0.048. Initial GCS of 14 was also associated with 3.9 times the risk to develop the primary outcome; however, the 95% CI contained the value of one (0.45-35), P value of 0.22, which is not statistically significant.

‘More than two discrete episodes of vomiting’ after the blunt head injury was the most common presenting symptom in children. But vomiting was not associated with abnormal brain CT in the cohort study. History of loss of consciousness post injury with abnormal brain CT was reported in only one patient (2.3%) out of 44 patients (97.7%) with odds ratio of 0.42 and 95% CI (0.05-3.2). This result concluded that there is no significant association between history of Loss of consciousness (LOC) and the CT finding of intracranial injury. Table 4 summaries the variables in terms of the injury mechanism, clinical manifestation and the outcome.

To determine which clinical symptoms are important predictors for abnormal brain CT in children with minor head trauma, a logistic regression method was used. Independent variables that were entered in the equation were: Age, sex, GCS, vomiting, headache and history of LOC. None of the symptoms which were entered in the analysis were found to be a significant predictor for abnormal brain CT in children with minor head trauma [Table 5].

Injury mechanism was evaluated for prediction using the logistic regression and it showed none of the independent variable to be a predictor for abnormal brain CT [Table 5]. However, when applying the forward method in logical regression, ‘fall of more than 1.5 meters or five stairs’ was found to be a predictor for abnormal brain CT in children with minor head trauma with odds ratio of 4.4 and P value 0.04 [Table 6].

## DISCUSSION

Less than 5% of patients with minor head trauma do have abnormal brain CT findings and none required neurosurgical intervention. The prevalence of abnormal brain CT in minor head injury is comparable with the international figure where the prevalence was reported to be between 7-10% and the surgical intervention was reported to be between 1-5%.[9,10]

Age was not associated with increased risk for intracranial injury with abnormal brain CT post blunt trauma. Only 2.9% of children aged one to three years were reported to have abnormal brain CT compared to approximately 3-10% as per previously

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**Table 3: Symptoms at presentation**

| Symptoms                         | Number (%) |
|----------------------------------|------------|
| Initial score on Glasgow coma scale |            |
| 15                               | 272 (93.8) |
| 14                               | 11 (3.8)   |
| 13                               | 7 (2.4)    |
| Vomiting                         | 88 (30.4)  |
| Loss of consciousness            | 89 (30.8)  |
| Headache                         | 44 (15.2)  |
| Seizure                          | 12 (4.2)   |
| Amnesia                          | 3 (1)      |

**Table 4: Associations between mechanism of injury, clinical manifestation and abnormal brain CT**

| variable                  | brain injury on CT n = 14 | no brain injury n = 275 | or (95% CI) |
|---------------------------|---------------------------|-------------------------|-------------|
| Fall n (%)                | 7 (4.6)                   | 145 (95.4)              | 0.89 (0.306-2.6) |
| MVA* n (%)                | 2 (3.3)                   | 63 (95.4)               | 0.573 (0.23-2.6) |
| Pedestrian n (%)          | 1 (4.2)                   | 23 (95.8)               | 0.84 (0.11-6.7) |
| Direct impact n (%)       | 4 (9.3)                   | 38 (90.5)               | 2.5 (0.75-8.35) |
| Assault n (%)             | 0 (0)                     | 5 (100)                 | na          |
| Child abuse n (%)         | 0 (0)                     | 1 (100)                 | na          |
| age                       |                           |                         |             |
| ≤3                        | 3 (2.9)                   | 100 (97.1)              | 1           |
| 4-5                       | 3 (6.2)                   | 42 (93.3)               | 0.5 (0.106-2.5) |
| 6-9                       | 4 (5.6)                   | 68 (94.4)               | 1.2 (0.25-5.5) |
| ≥10                       | 4 (5.8)                   | 65 (94.2)               | 0.96 (0.23-4) |
| sex                       |                           |                         |             |
| male                      | 21 (6.3)                  | 293 (93.7)              | 5.5 (0.711-42.9) |
| female                    | 3 (1.2)                   | 82 (98.8)               |             |
| GCS                       |                           |                         |             |
| ≤15                       | 22 (4.3)                  | 260 (95.6)              | 1           |
| 16-17                     | 2 (1.2)                   | 98 (98.8)               | 3.9 (0.44-35) |
| ≥18                       | 1 (14.3)                  | 6 (85.7)                | 5 (1.1-27)  |
| vomiting                  | 6 (6.8)                   | 82 (93.2)               | 1.76 (0.6-5.2) |
| headache                  | 1 (2.3)                   | 43 (97.7)               | 0.42 (0.003-3.2) |
| LOC                       | 5 (5.6)                   | 84 (94.4)               | 1.26 (0.4-3.9) |

*MVA: MOTOR VEHICLE ACCIDENT
published international reports.\[10,16\] Younger age-group with minor head trauma was found in the cohort study to carry no specific risk for intracranial injury. However, this age-group was not the main focus of our study.

Gender difference is well documented in literature where male sex accounted for the majority of patients with minor head trauma.\[17\] The risk of intracranial injury in minor head trauma was higher in males compared to females; however, the risk was not statistically significant. With regard to different injury mechanisms, short distance falls and motor vehicle accidents were reported to be the most common injury mechanisms in our study. However, in the univariate analysis for the risk association, ‘fall’ was not significantly associated with intracranial injury as the majority of fall was over short distance. Of the 21 cases of long distance fall, abnormal brain CT was reported in three cases (14.3%). Given this percentage, the risk of association between the long distance fall and intracranial injury was not well-supported in the univariate analysis. Analysis did not support the association between intracranial injury and MVA as a mechanism of minor head trauma, though it was difficult in the study to divide the data of MVA into ‘low’ or ‘high speed impact’. Pedestrians were not found to be associated with intracranial injury and this could be due to the consideration that most of the cases who fit the definition of minor head injury have had low speed impact. Direct head impact in our review was reported with a frequency of 9.2%. Direct head impact was considered as crush head injury from the direct impact of a heavy object on the head. In the study, the direct impact injury in young children usually happened at households due to falling pieces such as furniture, television and the oven. Children with direct head impact had two times the risk of intracranial injury; however, this association was not statistically significant and this could be due to the relatively small sample size.

With respect to the clinical manifestations in association to intracranial injury, vomiting occurred in 30% of the cases, but only 6.8% was found to have intracranial injury. Vomiting post head trauma does carry risk of association with intracranial injury although this finding was not statistically significant. We believed that vomiting does occur frequently in children with intracranial injury but also occurs in patients with other medical causes as reported from previous studies.\[18-21\] Vomiting as an isolated symptom in relation to intracranial injury showed a poor association.

GCS at presentation to the hospital was the only clinical finding that had a statistically significant association with intracranial injury in our study. Patients with GCS of 13 at presentation to ED were found to have five times more risk of having intracranial injury compared to GCS of 14-15 at presentation. Yet intracranial injury had occurred in patients with normal GCS at presentation as reported in 4% of the cases in our study. LOC of duration less than 5 minutes with intracranial injury was reported in 5% from all LOC cases with estimated risk of one and half times. In general, LOC with the time duration that was proposed in our study was not statistically significant. Having said that, LOC of longer duration as reported from previous studies was found to be associated with intracranial injury.\[19\]

Clinical manifestations that were presented in the previous section were analyzed employing a predictive model. We studied them as a constellations of manifestations and it was found that patients with GCS of 13 at presentation is the only important clinical predictor of intracranial injury. Fall from long distance of more than 1.5 meters or more than five stairs was found

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**Table 5: Symptoms & injury mechanism that predictor of abnormal brain CT (logistic regression; enter method)**

| Variables                  | P value | Odds Ratio | 95% C.I for exp (b) |
|---------------------------|---------|------------|---------------------|
| sex (1)                   | 0.177   | 4.230      | 0.222 - 34.266      |
| GCS (1)                   | 0.332   | 2.665      | 0.343 - 19.149      |
| GCS (2)                   | 0.063   | 6.266      | 0.905 - 43.379      |
| vomiting (1)              | 0.298   | 2.738      | 0.537 - 13.125      |
| headache (1)              | 0.155   | 3.247      | 0.200 - 1.836       |
| LOC (1)                   | 0.233   | 3.633      | 0.626 - 21.077      |
| age 2                     | 0.516   | 2.171      | 0.339 - 13.125      |
| age 1                      | 0.206   | 3.040      | 0.646 - 16.524      |
| age 2                      | 0.206   | 3.040      | 0.646 - 16.524      |
| age 3                      | 0.450   | 3.533      | 0.626 - 21.077      |
| constant                   | 0.000   | 0.004      | 0.000 - 1.373       |
| MVA* (1)                  | 0.598   | 1.126      | 0.101 - 19.594      |
| pedestrian (1)            | 0.063   | 3.004      | 0.146 - 65.572      |
| direct impact (1)         | 0.239   | 4.019      | 0.261 - 61.812      |
| fall                      | 0.100   | 0.105      | 0.007 - 0.105       |
| fall short* (1)           | 0.714   | 6.418      | 0.343 - 120.633     |
| constant                   | 0.007   | 0.026      | 0.000 - 0.127       |

*Motor vehicle accident, ‘short distance fall less than 1.5 meter, long distance fall more than 1.5 meter.

**Table 6: Symptoms & mechanism of injury predictor of abnormal brain CT (logistic regression; forward LR)**

| Variables                  | OR     | P Value |
|---------------------------|--------|---------|
| sex (1)                   | 3.346  | 0.067   |
| GCS (1)                   | 5.961  | 0.012   |
| GCS (2)                   | 4.413  | 0.016   |
| vomiting (1)              | 1.169  | 0.301   |
| headache (1)              | 0.745  | 0.388   |
| LOC (1)                   | 0.467  | 0.017   |
| age 2                     | 1.373  | 0.712   |
| age 1                      | 0.384  | 0.535   |
| age 2                      | 0.510  | 0.746   |
| age 3                      | 0.379  | 0.673   |
| overall statistics        | 13.896 | 0.126   |
| MVA (1)                   | 0.527  | 0.468   |
| pedestrian (1)            | 0.026  | 0.872   |
| direct impact (1)         | 2.334  | 0.127   |
| fall                      | 4.957  | 0.084   |
| fall short (1)            | 1.601  | 0.206   |
| fall long (1)             | 4.379  | 0.016   |
| overall statistics        | 7.632  | 0.178   |
to be a strong predictor for intracranial injury in children with minor head trauma. Direct head impact was not a predictor for intracranial injury despite the reported consideration that patients with direct head impact had twice the risk of having intracranial injury over those due to other mechanisms.

The study was conducted retrospectively and thus may present some limitations on the amount of data availability which may lead to information bias. Sample size is small and this may have affected the study ability to detect relatively small to moderate but important clinical manifestations that might well predict intracranial injury. Given the fact of the limited predictive rule that was derived from this review, the decision to determine which patients should undergo neuroimaging is encouraged to be based on clinical judgments. Given the high rate of radiation exposure compared to the small number of positive brain CT findings, a period of clinical observation the segment of ‘children with minor head injury, but otherwise healthy’ is highly recommended.

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