THE USE OF CLINICAL DECISION RULES TO REDUCE UNNECESSARY HEAD CT SCANS IN PEDIATRIC POPULATIONS

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Abstract

Background: Head computed tomography (CT) imaging is the gold standard study for rapidly identifying emergent traumatic brain injuries (TBIs). Exposure to the ionizing radiation utilized in CT increases lifetime risk for developing neoplasms. Currently there is little consensus on appropriate use of CT imaging for children with mild head injury. Clinical decision rules (CDRs) have been developed to identify children at very low risk of clinically significant brain injury. While these CDRs have been validated, their implementation has not been as well studied.

Objective: To evaluate the efficacy of two CDRs in decreasing CT scan rate without missing clinically significant brain injuries. The two CDRs used in this study were the Children's Head Injury Algorithm for the Prediction of Important Clinical Events (CHALICE) and the Pediatric Emergency Care Applied Research Network (PECARN) algorithm. Both variations of the PECARN criteria for age 2 years and older and age <2 years were studied.

Design/Methods: The medical records for patients with the diagnosis of head injury evaluated at the Maricopa Medical Center Pediatric Emergency Department for all of 2011 and 2012 were reviewed. A total of 331 charts were identified. The PECARN and CHALICE inclusion criteria and algorithms were applied to these charts to determine if the patients met criteria for CT scan. Patients with suspected non-accidental injuries were excluded.

Results: Of 331 patients, 238 met the inclusion criteria for CHALICE. 96 (40.3%) had CT scans performed. According to the algorithm, only 52 (21.8%) met criteria, which is an absolute rate reduction of 18.5%. One TBI was missed. 129 patients met the inclusion criteria for PECARN age 2 years and older. 73 (56.6%) had CT scans performed. 61 (47.2%) met criteria resulting in an absolute rate reduction of 9.4%. No TBIs were missed. 74 patients met inclusion criteria for PECARN age <2 years. Of these, 25 (33.7%) had CT scans performed and the same number met criteria resulting in no change in number of scans. One TBI was missed.
**Conclusions:** Both the CHALICE and PECARN CDRs have the potential to reduce scan rates in our home institution. The CHALICE CDR would have resulted in a greater reduction in CT scans. PECARN also would have reduced the number of scans in children 2 years and older, but not in children <2 years old. The TBI that did not meet CDR criteria was also missed by clinical suspicion and a CT scan done on a later encounter was suspicious for a non-accidental injury.
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Background/Significance

Traumatic brain injury (TBI) in pediatric populations is a major public health problem. In the USA, head trauma in individuals aged 18 years and younger results in approximately 7400 deaths every year.\textsuperscript{1,2} Head injury is the most common type of injury in children and occurs at an annual rate of 60 to 100 per 100,000 persons.\textsuperscript{7} Head injuries account for approximately 5% of all emergency department visits, with a large proportion of these being children.\textsuperscript{16} In all, there are 650,000 to 1 million pediatric ED visits per year for head injuries with 95,000 hospital admissions at a cost of over $1 billion per year.\textsuperscript{5-7,18,33}

Mild TBI is the most commonly traumatic brain injury assessed in emergency departments. A mild TBI is defined as a head injury with a Glasgow Coma Scale (GCS) greater than 12 with a history of loss of consciousness (LOC).\textsuperscript{23,26} When a child with a head injury presents to the ED, it is important for clinicians to rapidly identify the presence of clinically significant brain injuries, especially in neurosurgical emergencies. The risk of a clinically significant TBI in these patients, however, is very low. Fewer than 10% of mild head injury patients have an abnormality on CT scan imaging, and of these, only a fraction require an intervention.\textsuperscript{18}

The definition of what constitutes a clinically significant brain injury has not been agreed upon. Any brain injury resulting in death, requiring prolonged intubation or hospitalization, or requiring any neurosurgical intervention would be considered clinically significant. However, beyond those obvious examples, there is not a consensus. Furthermore, it is not uncommon that CT imaging might identify minor or unrelated findings not relevant for the acute management of the patient; many traumatic brain injuries identified on CT do not require any sort of intervention and some are also false positives. The importance of identifying those traumatic brain injuries that ultimately do not require any intervention has not been determined.
Computed tomography (CT) imaging is the gold standard study for rapidly identifying emergent traumatic brain injuries.\textsuperscript{18} Evidence suggests that patients with negative findings on CT and no neurologic deficits can be safely discharged home following a head injury.\textsuperscript{3,23-25} For this reason, the use of CT in head injuries has been on the rise: in Canadian PEDs the use of CT in minor head injury increased from 15\% in 1995 to 53\% in 2005.\textsuperscript{31,32} Currently, about 50\% of children assessed in North American EDs for head injury receive CT scans.\textsuperscript{18} CT imaging, while an effective modality, is not without risk. Exposure to the ionizing radiation utilized in CT increases the patient’s lifetime risk for developing a fatal neoplasm. It has been estimated that there is one fatal cancer for every 1000 - 1400 CT brain scans performed in young children.\textsuperscript{13-15} An estimated 1 million children every year are unnecessarily imaged with CT.\textsuperscript{13-15} For this reason, both the National Cancer Institute and the Federal Drug Authority have recommended a reduction in radiation exposure and the risk of subsequent cancers by eliminating unnecessary CT.\textsuperscript{1,2,30}

Currently there is little consensus about when a child with a mild head injury should receive a CT scan.\textsuperscript{9,11,12,10} For this reason, clinical decision rules (CDRs) have been developed to help determine when a patient with a mild head injury is at very low risk for having a clinically significant head injury. A clinical decision rule incorporates three or more variables from the history, physical examination or simple tests into a tool that helps clinicians to make diagnostic or therapeutic decisions at the bedside.\textsuperscript{32} In the case of head injuries, these rules help the physician to determine whether the child might require a CT scan or, instead, can safely be observed or discharged. There are many reasons why a CDR for mild head injuries should be implemented in EDs. These include: mild TBIs are a common ED presentation, there is potential for an avoidable poor outcome, there is currently a large variability in practice, CT rates have dramatically been increasing, and ionizing radiation from CT causes fatal neoplasms.\textsuperscript{17}
CDRs for head injury vary significantly in their details; they each employ different predictor variables, apply to different populations, include different inclusion and exclusion criteria, and suggest different courses of action.\textsuperscript{16,17} There is no clear consensus as to which CDR would be the best to implement. A review article published in 2009 by Maguire et al compared identified 8 CDRs for children with head injuries.\textsuperscript{20} Of those, the children’s head injury algorithm for the prediction of important clinical events (CHALICE) was the largest with 22,772 subjects enrolled aged 0 to 16. Later that year, the Pediatric Emergency Care Applied Research Network (PECARN) published their CDR which was derived and validated in a population of 42,412 children. Other CDRs reviewed were limited by a small sample size and have been excluded from this study.\textsuperscript{20}

The PECARN CDR by Kupperman et al derived and validated age-specific prediction rules for clinically important intracranial injuries in a prospective cohort study that analyzed 42,412 patients younger than 18 years of age in 25 North American EDs who presented within 24 hours of minor blunt head trauma with a GCS score between 14 and 15. It excluded patients with trivial mechanisms of injury, including ground-level falls or running or walking into stationary object. It also excluded patients with no signs and symptoms of head trauma other than scalp abrasions and lacerations. The prediction rule includes separate criteria for children less than 2 years old and greater than 2 years old. For the population less than 2 years of age, the criteria are: abnormal mental status per caregiver, presence of LOC, presence of scalp hematoma or palpable skull fx, and increased severity of the mechanism of injury. In their population, the CDR was determined to have a sensitivity and negative predictive value of 100% and would result in a 25% reduction in the scan rate. For the greater than 2 year old population, the criteria are: changes in mental status, presence of LOC, headache, vomiting, basilar skull fracture, and increased severity of the mechanism of injury. In their population, the CDR had a sensitivity of 96.8% and a NPV of 99.95% and would result in a 20% reduction in the CT scan rate.
An implementation study of the PECARN CDR at a tertiary care academic pediatric ED in Italy found that it had an adherence rate of 93.5% and that medical staff were more satisfied with it versus previous, more complex internal guidelines (96% vs 51%).

The CHALICE CDR by Dunning et al was a prospective cohort study enrolling 22,772 children attending EDs in 10 hospitals in the UK ages 0 - 16. Notably, pediatric patients aged 17 were excluded. The criteria took into account elements from the history, examination, and the mechanism of injury. For the history they include: LOC, amnesia, abnormal drowsiness, vomiting, suspicion of non-accidental injury, and seizure. From the examination: GCS, suspicion of penetrating or depressed skull injury or tense fontanelle, signs of basal skull fracture, positive focal neurology, presence of bruise, swelling, or laceration. From the mechanism: high-speed road traffic accident, fall of >3m in height, and high-speed injury from a projectile or object. This CDR was derived with a sensitivity of 98% and a specificity of 87% for the prediction of clinically significant head injury, and resulted in a CT scan rate of 14%. 
Methods

All pediatric patients aged 0 to 17 were identified using ICD-9 codes for closed head injuries seen at Maricopa Medical Center’s Pediatric Emergency Department (MMC PED) in 2011 and 2012. The MMC PED cares for more than 20,000 children each year, ranging from infants to adolescents. Attending physicians affiliated with this emergency department are trained in pediatrics and pediatric emergency medicine. During their visits, patients were seen by resident and attending physicians.

Patients were excluded from the study if they had an unclear history of trauma, had a history of multiple head injuries, were developmentally delayed, had a history of prior intracranial pathology or trauma, had a suspected non-accidental injury, or had comorbid medical conditions which would preclude the application of the CDRs.

Our study specifically focused on the patient population that sought care at MMC PED in 2011 and 2012 for evaluation of a closed head injury to see if previously validated CDRs applied at presentation would reduce the number of CT scans without missing clinically significant brain injuries. While the definition of clinically significant brain injury has not been agreed upon, for the purpose of this study we used the following: death from a traumatic brain injury, neurosurgical intervention for traumatic brain injury (intracranial pressure monitoring, elevation of a depressed skull, ventriculostomy, hematoma evacuation, lobectomy, tissue debridement, dura repair, other), intubation for traumatic brain injury, hospital admission for traumatic brain injury, and any other abnormality seen on CT which is due to the head trauma.

Based on the clinical information in the patient’s chart, we determined which patients from our population would have been classified as either high risk for clinically significant brain injury for each of the two CDRs, thereby requiring a cranial CT scan, and those who would have been considered low risk and would not have required a scan. All notes from the PED, including triage nurse’s note, the resident’s note, and the attending physician note, were reviewed to ascertain the presence of any of the above noted criteria. These notes include comment areas in which the physician’s assessment and plan could be described. Details of the history and
physical were used to determine if the patient would have qualified for a cranial CT scan if the CDRs were in use. The patient's complete electronic health record was also reviewed to ensure that a CT was not performed which was not documented in his PED note.

We then calculated the number of CT scans indicated by each CDR to compare to the actual scan rates for the years 2011 and 2012 at MMC PED. This allowed us to determine if a reduction in CT scans could be achieved without missing clinically significant brain injuries with the application of CDRs.
Results

PECARN

The PECARN CDR divides patient populations into two groups: children less than two years old and children two years and older. 129 patients met the inclusion criteria for PECARN age two years and older. Of these, 73 (56.6%) had CT scans performed. 61 (47.2%) met criteria for CT scan, resulting in an absolute rate reduction of 9.4% and a potential reduction of 12 CT scans. No TBIs were missed by the CDR. In the PECARN less than age two group, 74 patients met the CDR inclusion criteria. 25 (33.7%) had CT scans performed and the same number met criteria resulting in no difference in the number of scans. One TBI was missed; however it did not meet the abovementioned criteria for clinical significance. A CT scan performed at a subsequent visit was suspicious for nonaccidental injury.
Fig. 1 CT scan rate in patients $\geq 2$ years old

Current practice

PECARN CDR
Fig. 2: CT scan rate in patients
A total of 331 patients were included in the study. Of these, 238 met the inclusion criteria for the CHALICE CDR. 96 (40.3%) received CT scans. According to the algorithm, only 52 (21.8%) met criteria, which is an absolute rate reduction of 18.5%. Strict application of the CHALICE CDR in this patient population would have resulted in 44 fewer CT scans. One TBI was missed; however it did not meet the abovementioned criteria for clinical significance. A CT scan performed at a subsequent visit was suspicious for nonaccidental injury.
Fig. 3: CT scan rate in all patients

Current practice  CHALICE CDR
Discussion

Both the PECARN and CHALICE clinical decision rules identify children at very low risk for clinically significant head injuries. Both of these rules were developed and validated in large populations. The effect of their implementation, however, has been less well studied. Our study sought to address this. By retrospectively applying both the PECARN and CHALICE CDRs to a population who sought care for pediatric closed head injuries at MMC in 2011 and 2012, we were able to compare them to see which could have resulted in the lowest scan rate without missing clinically significant head injuries.

Both the CHALICE and PECARN CDRs have the potential to reduce scan rates in our home institution. The CHALICE CDR would have resulted in a greater reduction in CT scans. PECARN also would have reduced the number of scans in children 2 years and older, but not in children less than 2 years old. The TBI that did not meet CDR criteria was also missed by clinical suspicion and a CT scan done on a later encounter was suspicious for a non-accidental injury. The exact date of the injury seen on that CT scan would therefore be unclear.

Our findings highlight the importance of improving appropriate CT use in pediatric populations. Clinical decision rules have the potential to improve appropriate use, thereby decreasing costs and exposure to ionizing radiation. An estimated 1 million children are unnecessarily imaged with cranial CT in the United States.\(^\text{15}\) Currently there is substantial variation in cranial CT use in the management of pediatric populations with minor head injuries. Our data suggests that the strict application of either the CHALICE or PECARN CDRs would result in fewer unnecessary cranial CTs without missing clinically significant head injuries, with the CHALICE CDR resulting in a larger decrease when compared with the PECARN CDR.
Our study has the following limitations. First, our study was conducted in a single academic pediatric emergency department, raising the possibility that our results may not be generalizable to other settings, particularly general EDs that care for children and may or may not employ board-certified pediatric emergency physicians. Data suggests that general emergency physicians obtain CT scans at a higher rate than board-certified pediatric emergency physicians. Therefore, the implementation of CDRs in community EDs may result in an even further decrease in the number of CT scans. Second, the data was abstracted from the medical record for our study participants and was subject to the limitations in documentation by providers. Third, we did not perform clinical follow-up on patients discharged from the PED without a CT scan, although we did review all medical records after the initial PED visit for any return visits.

Our study sought to examine the role of clinical decision rule use in reducing head CT scans in pediatric head injuries without missing clinically significant head injuries. Our data suggests that both the CHALICE and PECARN CDRs have the potential to achieve this, with the CHALICE CDR achieving a greater reduction in scans. Neither CDR missed a clinically significant head injury in our patient population. Future work could include the prospective application of both CDRs in the same population to determine which would have the greatest reduction in scans without missing clinically significant head injuries.
Literature Cited


