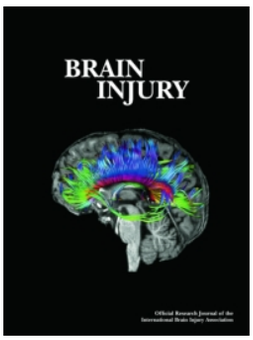

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Pediatric minor head trauma in Brazil and external validation of PECARN rules with a cost-effectiveness analysis

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ABSTRACT

Background: Pediatric minor head trauma approaches aim to ensure the absence of traumatic brain lesions, minimize ionizing radiation, and enhance cost control. We evaluated the applicability and cost-effectiveness of the Pediatric Emergency Care Applied Research Network (PECARN) rules after head trauma and rationalize the use of head computed tomography (CT) scans.

Methods: We retrospectively divided patients <18 years old who presented at a single institution in Brazil with minor head trauma into four groups: Group I (skull X-ray only), Group II (head CT only), Group III (X-ray and CT), and Group IV (observation only). Direct costs were calculated based on examination and length of hospitalization. The PECARN rules were applied retrospectively in each patient to determine who required a CT scan, and the costs were re-calculated.

Results: Of the 1328 patients, CT scans were performed in 36.4% and X-rays in 52.6%. The mean cost was USD 5.88, 34.58, 41.85, and 4.04 for Groups I–IV, respectively. After applying the PECARN rules, 77.6% of patients no longer required a CT scan, and overall costs were reduced from USD 16.71 to 7.88 ($p < .001$).

Conclusion: The PECARN rules demonstrated a meaningful cost-effectiveness and should be applied to the Brazilian pediatric population.

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KEYWORDS
Brain injury; validity; protocol; pediatric neurosurgery

Introduction

Minor head trauma in the pediatric population is a global health issue, and an estimated half a million patients <14 years old are admitted to the emergency room for this condition each year in the United States (1–3). In Brazil, an estimated 30,000 pediatric patients incur a head trauma and are admitted to the hospital each year, corresponding to a total cost of 12 million dollars (4). Although epidemiological data on pediatric minor head trauma are scarce in Brazil, some descriptive studies have warned of the high rates of skull radiographs for screening, computed tomography (CT) scans, and the increasing concern regarding radiation risk (5,6).

When assessing minor head trauma in the pediatric population, it can be challenging to determine which patients have intracranial traumatic abnormalities and should receive a head CT. Although CT is undoubtedly useful for identifying intracranial hemorrhage, the ionizing radiation increases the risk of developing malignant neoplasms, particularly in children (7,8). Moreover, a CT approach is more suitable in children <2 years old than in older children because their undeveloped language skills result in an unreliable clinical examination (9).

Several protocols have been created to decrease the number of head CTs performed in children with minor head trauma. The Pediatric Emergency Care Applied Research Network (PECARN) study was a multicentric prospective study that was performed in 25 hospitals in the United States to identify children at a very low risk of clinically important brain injury who do not require head CT (10). The PECARN rules have been validated in North America, Europe, and Japan, and its accuracy has already been compared with other protocols (11–16). However, the PECARN rules have not yet been validated in South America, and few studies have been performed to assess its cost-effectiveness (17). Thus, this study aimed to assess the applicability and cost-effectiveness of the PECARN protocol in Brazil.

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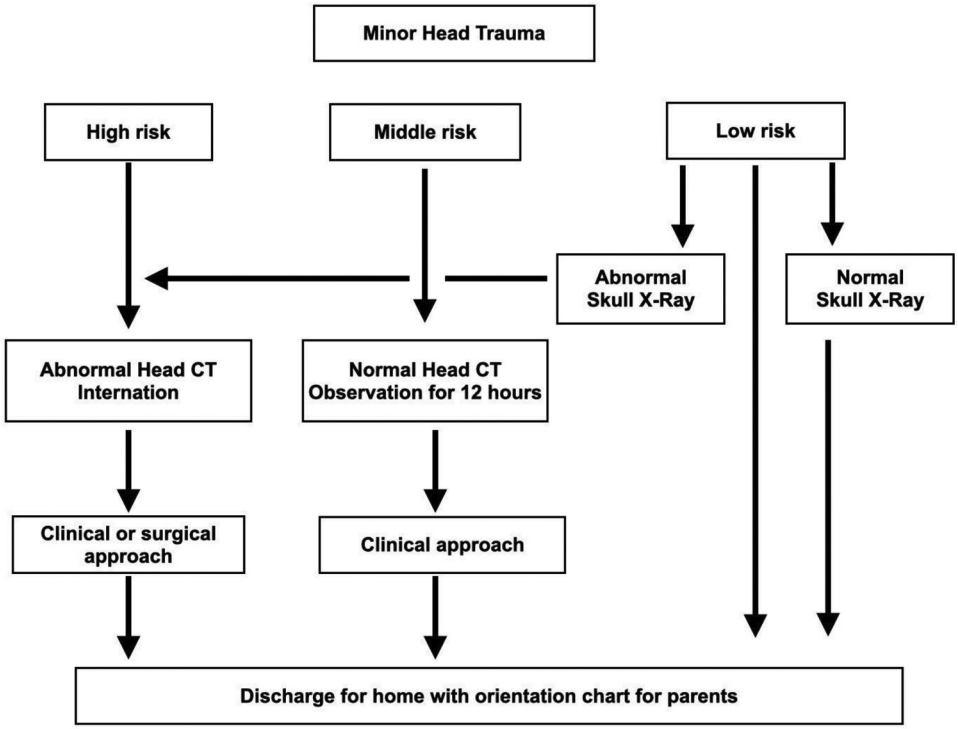

Figure 1. Flow chart of the standard minor head trauma approach used in our trauma referral center.

Materials and methods

Study population

Following ethicalboard approval(CAAE: 67842617.0.0000.5119), a retrospective observational study was performed from January to December 2016 that included all pediatric patients presenting at the João XXIII hospital who had suffered a minor head trauma within 24 hours of admission. The study population was defined as all patients who had a traumatic lesion on the head and presented with a Glasgow coma scale (GCS) score of 13, 14, or 15 at admission, in agreement with the Brazilian Society of Neurosurgery (18).

We excluded all patients who scored <13 on the GCS; those with a history of penetrating head trauma; those with preexisting neurological disorders, intracranial shunts, bleeding disorders, and known intracranial lesions such brain tumors; and those without enough data to be properly evaluated. For the purpose of this study, mild traumatic brain injury, which is defined as the physiological disruption of brain function resulting from traumatic force transmitted to the head (19), was considered to be synonymous with concussion, and both were included in the group of patients with minor head trauma.

João XXIII hospital is a public teaching hospital and trauma referral center in Belo Horizonte, the capital of Minas Gerais, in southwest Brazil. This metropolitan region contains approximately 5 million inhabitants. The hospital belongs to the State Hospital Foundation, includes 400 hospital beds, and is a referral hospital for emergencies. An average of 13,000 patients are treated every month, of whom 4,000 are children (20).

In this referral center, minor head trauma is usually assessed following the protocol suggested by the Brazilian Society of Neurosurgery, in which minor head trauma is classified as high, middle, or low risk based on the risk features presented by the patient. High risk was defined as a patient presenting with non-accidental trauma and signs of skull base fracture, such as raccoon eyes and Battle's sign. Middle risk was defined as children who suffered a high-intensity trauma mechanism, and low risk was defined as asymptomatic children who experienced a low-intensity trauma mechanism. This protocol gives the choice of performing a skull X-ray for low-risk minor head trauma and recommends CT for middle- and high-risk patients (18) (Figure 1).

Usually, the children are evaluated by a pediatrician who uses this protocol for the management of minor head trauma. The criteria used to refer the patient to a neurosurgeon depend on the personal experience of the pediatrician; there are no standard criteria.

Data collection

We retrospectively collected and analyzed data pertaining to patient demographics, injury mechanism, skin injury, clinical presentation, and the specialist responsible for determining which examinations were required and discharge from the hospital. According to the approach used, the patients were classified into four groups: Group I (skull X-ray only), Group II (head CT only), Group III (X-ray and CT), and Group IV (observation only). Then, the PECARN criteria were retrospectively applied to each patient to determine which patients were not recommended to receive a CT scan under these

criteria. The new costs were then simulated and obtained based on this classification.

According to PECARN original research, clinically important brain injury is defined as follows: if the patient has dead due to traumatic brain injury (TBI), underwent neurosurgical procedures, was intubated for TBI for 24 hours or longer, or was admitted to the hospital for two or more nights in association with TBI identified via CT. They also defined hospital admission for TBI when persistent neurological symptoms or signs such as persistent alterations in mental status, recurrent emesis, persistent severe headache, or ongoing seizure management were present.

According to the PECARN rules, the recommendations regarding CT were divided based on whether the patient was younger or older than 2 years. For those younger than 2-years old, CT was considered if the child presented with a GCS score of 14, other signs of altered mental status or palpable skull fracture, occipital or parietal, or temporal scalp hematoma, a history of loss of consciousness for more than 5 s, a severe mechanism of trauma, or behavior alterations according to the parents. For those older than 2 years, CT was considered if there was a history of altered mental status, a GCS score of 14, signs of basilar skull fracture, a history of loss of consciousness, vomiting, severe headache, or a severe mechanism of injury.

To apply the PECARN criteria in this retrospective sample, we only considered objective data when determining whether a CT was necessary. In this line, we included all patients who presented with a GCS score of 13 or 14; loss of consciousness for more than 5 s; report of skull fracture by physical exam; and severe mechanism of trauma if the record specified that there was a high fall of more than 0.9 m in children less than 2-years old or >1.5 m in children older than 2-years old; motor vehicle crash causing ejection of the patient, death of another passenger, or rollover; or if the patient was a pedestrian or bicyclist without a helmet who was struck by a motorized vehicle. Subjective information such altered mental status not specified, behavior alterations according to the parents, headache, and vomiting were considered as criteria for CT in this study because it was a retrospective study and such information is expected to be imprecise.

The length of hospital stay and the examination performed were used to calculate the direct costs. These values were extracted based on information found in the Brazilian Health System database (21): a skull X-ray cost USD 1.89, a CT cost USD 24.42, and a one-hour hospital stay cost USD 1.31.

Table 1. Characteristics of the 1,328 Brazilian pediatric patients who suffered minor head injury according to the PECARN criteria and the Brazilian Society of Neurosurgery guidelines.

	Less than 2 years old (n = 639)	2 years or older (n = 689)
Glasgow Coma Scale score		
15	571	609
14	49	74
13	19	6
Severe mechanism of trauma*	100	130
Loss of consciousness[c]	11	25
Skull fracture in physical exam	0	1
Classification by "Projeto diretrizes"		
Low risk	380	404
Middle risk	157	154
High risk	102	131
Skull X-ray	334	364
CT scan	223	261
CT recommended by PECARN rules	127	170
Clinically important[P]	20	30
Sum	639	689

[a]All patients with a Glasgow Coma Scale score of 13 or 14 matched the PECARN criteria.*Falls from a bicycle without a helmet, struck by a motorized vehicle, falls from rooftops and falls >0.9 m for children less than two years old or >1.5 m in those older than two years.[c] All patients with this criteria were included.[P] Patients with persistent behavior abnormalities and symptoms such as vomiting.

Statistical analysis

SPSS v20 (IBM Corp., Armonk, NY), Minitab 16 (Minitab Inc., State College, PA), and Excel Office 2010 (Microsoft, Redmond, WA) software were used for the statistical analyses. A confidence interval of 95% was applied. An analysis of variance was used to evaluate the differences among the mean costs of the four groups. The two-proportion equality test (Chi-square) was used to compare the rates among the covariates of age and sex. Differences were considered significant at $p < .005$.

Results

We analyzed 1,328 children with a mean age of 4.25 years (standard deviation [SD] = 4.25, confidence interval [CI]: 0.23). The study population included 799 males and 529 females ($p < .001$). The primary injury mechanism was accidental head injury (1,305/1,328, 98.3%). Minor falls were the leading cause of injury (n = 553, 41.6%), followed by falls from the bed (n = 253, 19.1%), bicycles (n = 70, 5.3%), and rooftops (n = 50, 3.8%). Non-accidental mechanisms of head injury were reported in 23 (1.7%) patients, including 19 (82.6%) cases that occurred at home and 4 (17.4%) at school. Skin injuries were observed in 414 (31.2%) patients ($p < .001$). Thirty-six patients (2.7%) experienced a loss of consciousness after head trauma, and 20 (1.5%) patients presented with seizures after head trauma. Headache was observed in 252 (19.0%) patients, and 271 (20.4%) vomited following the head trauma. The main features of the patients in this study according to the PECARN criteria are presented in Table 1.

CT scans were performed on 484/1,328 (36.4%) patients. Skull X-rays were performed on 698/1328 (52.6%) patients, of which 644 (92.3%) scans were indicated by a pediatrician. A pediatrician was responsible for discharge to home for most of the patients (992/1,328, 74.7%), followed by neurosurgeons (231/1,328, 17.4%). No intracranial lesions were reported in patients who underwent a CT scan. There were one case of an orbital fracture and calvaria linear fractures.

Table 2. Cost differences between the four groups of patients classified according to the minor head trauma approach used.

	n	Mean cost (USD)	SD	CI	p value
Group I	629	5.64	3.02	0.24	<0.001
Group II	415	33.16	6.38	0.61	
Group III	69	40.13	16.4	3.88	
Group IV	215	3.87	4.10	0.55	

Group I, skull X-ray only; Group II, head CT only; Group III, X-ray and CT; Group IV, observation only
Abbreviations: SD, standard deviation; CI, confidence interval.

The differences between the four groups classified according to the approach taken and the mean direct costs are presented in Table 2.

When the PECARN protocol was applied to our study population, 1,031/1,328 (77.6%) patients was reconsidered did not perform a CT scan, and the mean cost was reduced from USD 15.74 to 7.42 ($p < .001$); the percentage of patients who should receive a total CT scan was reduced from 36.4% to 31.6%.

Discussion

Our study results revealed that skull CT was performed in 36.4% of cases, which was a lower rate than that reported in another study (at least 60%) (11). Interestingly, our rate could be attributed to the protocol used in our hospital, which was developed by the Brazilian Society of Neurosurgery in 2002 and named "projeto diretrizes;" this protocol stratifies minor head trauma as either mild, medium, or high risk based on severity features (18). However, this protocol was demonstrated as insufficient to avoid high rates of skull X-rays. Furthermore, when the PECARN rules were applied, the rate of CT was reduced to 31.6%, which significantly decreased the overall direct costs.

Skull fractures were observed in the minority of patients, and no intracranial hemorrhage, neurosurgical interventions, or deaths were noted in this retrospective analysis. Moreover, no patients presented with focal neurological impairment in the initial evaluation, and the majority presented with a GCS score of 15. The most common symptoms at clinical presentation were headaches and vomiting. This finding was corroborated in a meta-analysis that analyzed several variables that could predict intracranial injury in mild head trauma in 22,420 patients. This meta-analysis concluded that headache, vomiting, loss of consciousness, and seizures had a low relative risk, and a GCS score <15 and a focal neurological deficit presented a higher relative risk of intracranial lesions (22). Similarly, Geijerstam et al., who performed a meta-analysis of 24 studies with 24,249 patients predominantly with a GCS score of 15, revealed that for every 1,000 patients who suffered from mild TBI, one died and nine underwent neurosurgical interventions (23).

In the present study, falls were responsible for the minor head trauma in most of the children evaluated, with rooftop falls as the fourth most common mechanism. This injury mechanism is related to poor economic conditions and usually occurs in low-income children who live in ghettos and fall from rooftops during recreational activities such as flying kites. One attempt to address this reality was enacted by the Brazilian Society of Neurosurgery based on the ThinkFirst prevention programs and was named "Projeto pense bem: prevention of traumatic brain injury in children." This project focused on giving instructions to the population to minimize TBIs. Similarly, Frandoloso et al. reported the impact of lectures regarding seat belt use in the pediatric population (24).

Although several studies have demonstrated the ineffectiveness of skull X-rays to rule out intracranial traumatic abnormalities (25), in reality, our findings show that this examination is still performed on most pediatric patients with minor head trauma in Brazil. In the last decade, Melo et al. conducted a retrospective study evaluating 1,888 pediatric patients who suffered minor head trauma from Salvador city, Brazil, and found a skull X-ray rate of 51.8% (5). These authors also followed the "projeto diretrizes" for the management of minor head trauma, which gives permission to use skull X-rays for minor head trauma investigations. Conversely, if the PECARN rules were applied, the high rate of X-rays would be reduced, leading to an overwhelming reduction in hospitalization and costs. Interestingly, this information could also be useful for pediatricians who serve in the "frontlines" of emergency care, and according to the present study, are responsible for most of the hospital discharges of pediatric patients with minor head trauma. Undoubtedly, they could change this reality. These findings lead us to consider changing the previous protocol given the new evidence of the applicability of the PECARN criteria in Brazil.

A comparison among the four groups showed that the observational group had the lowest direct costs. The increased costs in the other groups were mainly attributed to performing X-rays or CT scans. Conversely, the OCTOPUS study, a randomized clinical trial that analyzed direct and indirect costs for 2,602 patients, concluded that patients given a CT had a lower cost than those who were merely observed (26). Undoubtedly, regional differences could affect the length of observation and thus the costs.

Our study has several limitations. The retrospective design could cause a biased interpretation of the results due to imprecise information. Furthermore, the PECARN criteria were not actually applied to the population; rather, a simulation was used to assess the performance. However, we do expect to implement the PECARN protocol in the future.

Hence, this study represents the first external validation of the PECARN criteria in Latin America and demonstrates a reduction in direct costs. Further, application of the PECARN criteria could decrease the rate of X-rays in our institution and optimize CT solicitations.

Declarations of interest

The authors report no conflict of interest.

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