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Original Article

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Head CT overuse in children with a mild traumatic brain injury within two Canadian emergency departments

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Abstract

Background: The validated Pediatric Emergency Care Applied Network (PECARN) rule helps determine the relevance of a head computerized tomography (CT) for children with mild traumatic brain injury (mTBI). We sought to estimate the potential overuse of head CT within two Canadian emergency departments (EDs).

Methods: We conducted a retrospective chart review of children seen in 2016 in a paediatric Level I (site 1) and a general Level II (site 2) trauma centre. We reviewed charts to determine the appropriateness of head CT use according to the PECARN rule in a random subset of children presenting with head trauma. Simple descriptive statistics were applied.

Results: One thousand five hundred and forty-six eligible patients younger than 17 years consulted during the study period. Of the 203 randomly selected cases per setting, 16 (7.9%) and 24 (12%), respectively from sites 1 and 2 had a head CT performed. Based on the PECARN rule, we estimated the overuse for the younger group (<2 years) to be below 3% for both hospitals without significant difference between them. For the older group (≥2 years), the overuse rate was higher at site 2 (9.3%, 95% confidence interval [CI]: 4.8 to 17% versus 1.2%, 95% CI: 0.2 to 6.5%, P=0.03).

Conclusion: Both EDs demonstrated overuse rates below 10% although it was higher for the older group at site 2. Such low rates can potentially be explained by the university affiliation of both hospitals and by two Canadian organizations working to raise awareness among physicians about the overuse of diagnostic tools and dangers inherent to radiation.

Keywords: *Brain injury; Head CT; mTBI; Overuse; PECARN.*

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Head computerized tomography (CT) use tripled in the past decade in the USA without increasing the rate of detection of life-threatening diagnoses (1,2). The estimated use of CTs has doubled in children from 1995 to 2005 (3). Some settings report CT use in approximately half of children with mild traumatic brain injury (mTBI) (3).

Considering the higher theoretical induced risk of cancer in children compared to adults (4–9), head CTs should be carefully prescribed to paediatric patients with signs and symptoms of mTBI that are concerning for intracranial injury that would benefit from hospitalization or neurosurgical intervention. In this context, Kupperman et al. (3) derived in 2009 a high sensitivity rule (3,10) to classify the risk (low, moderate, or high) of having a clinically important TBI (ciTBI) depending on the child's age group. For patients belonging to the low-risk category, the PECARN rule does not recommend a head CT, while it suggests it for patients belonging to the high risk category. Decision making for moderate risk patients is left to physician judgment and parental preferences.

OBJECTIVES

The main goal was to measure the head CT overuse rate for children with symptoms of mTBI within two Canadian university-affiliated emergency departments (EDs). The CT overuse rate was defined in this study as the ratio of the number of low-risk patients with a prescribed CT to the total number of low-risk patients.

METHODOLOGY

Design and setting

We conducted a retrospective chart review within two university-affiliated hospitals for the year 2016. The first setting, referred as site 1, was a Level I paediatric trauma care centre (CHU Ste-Justine, Montreal, QC, Canada), with an average of 80,000 annual visits to the ED (84,000 during the year 2016), with approximately 1,200 for head trauma. The second setting, referred as site 2, was a Level II general trauma centre (CISSS Chaudière-Appalaches – Hôtel-Dieu de Lévis, Lévis, QC, Canada) with an average of 66,000 annual visits per year (adults and children), including approximately 430 visits for head trauma.

Children under 17 years of age with a chief complaint of head trauma were eligible. Mandatory inclusion criteria were (1) that the head trauma occurred in the 24 hours prior to arrival to the ED and (2) a Glasgow Coma Scale score over 13. All transferred patients from other hospitals were excluded to avoid referral bias. Also, patients with a special condition that could have influenced the decision to order a head CT were automatically excluded (e.g., suspected child abuse).

Outcomes

The primary outcome was the overuse rate of head CT, as defined earlier.

Independent variables

The independent variables were the demographic data (age and sex) as well as other clinical information such as the mechanism of injury, the final diagnosis, and head CT results.

Procedure

All information related to the patient's visit to the ED such as blood test results or triage reports are recorded in the electronic health record (EHR) and stored in the hospital database. A query was programmed to identify eligible patients under the age of 17 who visited the ED from January 1, 2016 to December 31, 2016 and who had one of the following diagnosis codes: mTBI, epidural/subdural hematoma, maxillofacial trauma/fracture, cerebral herniation, cerebral contusion, diffuse axonal injury, intracerebral hemorrhage, polytrauma, mTBI, and falls. For each hospital, the query results were exported into a Microsoft Excel (Redmond, WA, USA) spreadsheet in which a random selection of medical charts was made with Kutools Microsoft Excel add-on.

All the randomly selected charts were then reviewed for inclusion/exclusion criteria based on physician medical notes, triage nurse reports, nurses' charted observation, trauma assessment, specialist consultation reports, and radiologist head CT results. Reasons for exclusion as well as demographic and specific data were recorded on a structured data form specifically designed for this research project.

For patients that did not receive a head CT when it was recommended (high-risk patients), we reviewed medical records to determine if the patient had returned to the ED after his discharge within the next 30 days. If a patient returned to the ED for any reason in the 30 days following the initial visit, we reviewed the medical chart to determine if a ciTBI was missed by the physician during this initial visit.

Data analysis

Before starting the analysis, we trichotomized all structured data forms into excluded patients, younger than 2 years or 2 years and older. We converted each category of structured data forms into a binary sequence in Microsoft Excel. We conducted double data entry verification as well as random verification (10% of the charts) to ensure the accuracy of the binary sequence. We then conducted two reliability measurements: one on inclusion/exclusion and one on the risk assessment. We measured inter-rater reliability using the kappa score (11,12). We analysed each of the three categories identified earlier separately. Each enrolled patient was classified according to his signs and symptoms into one of the following categories: low, moderate or high risk. We computed the overuse rate as defined earlier (see Section 'Objectives').

Statistical analysis

We performed statistical analyses using the online calculator *VassarStats* (13). We computed P values using Fisher's exact test and confidence intervals for the difference between two independent proportions as well as for single proportions using the Wilson score method without correction (12) as described by Newcombe (11).

Sample size

We determined our sample size with Krejcie and Morgan's (14) formula with a proportion of overuse of 0.5, a margin of error of 5% and a significance level of 5%. Applying this formula to the largest set corresponding to the query's result list from the level I trauma centre, it was calculated that a total of 203 patients needed to be enrolled from the level I trauma centre. For the purpose of comparison, it was decided to enroll the same number from the level II trauma centre. To reach this specific number, we reviewed a total of 286 randomly selected medical charts from site 1 and 309 from site 2 from the query lists.

Ethics

This study was approved by the ethics committees at both hospitals. Given the retrospective nature of this study, no written consent was required.

RESULTS

Baseline demographics

A total of 1,123 potentially eligible patients from site 1 and 423 from site 2 visited EDs during the study period. Among these, 286 and 309 patient charts, respectively from site 1 and 2, were randomly selected for full review. There were 83 patients from site 1 and 106 from site 2 that were excluded for reasons enumerated below. There were 203 patients per setting enrolled for review (see Figure 1). The main reason for exclusion was a delay of more than 24 hours following the traumatic injury before arrival to the ED.

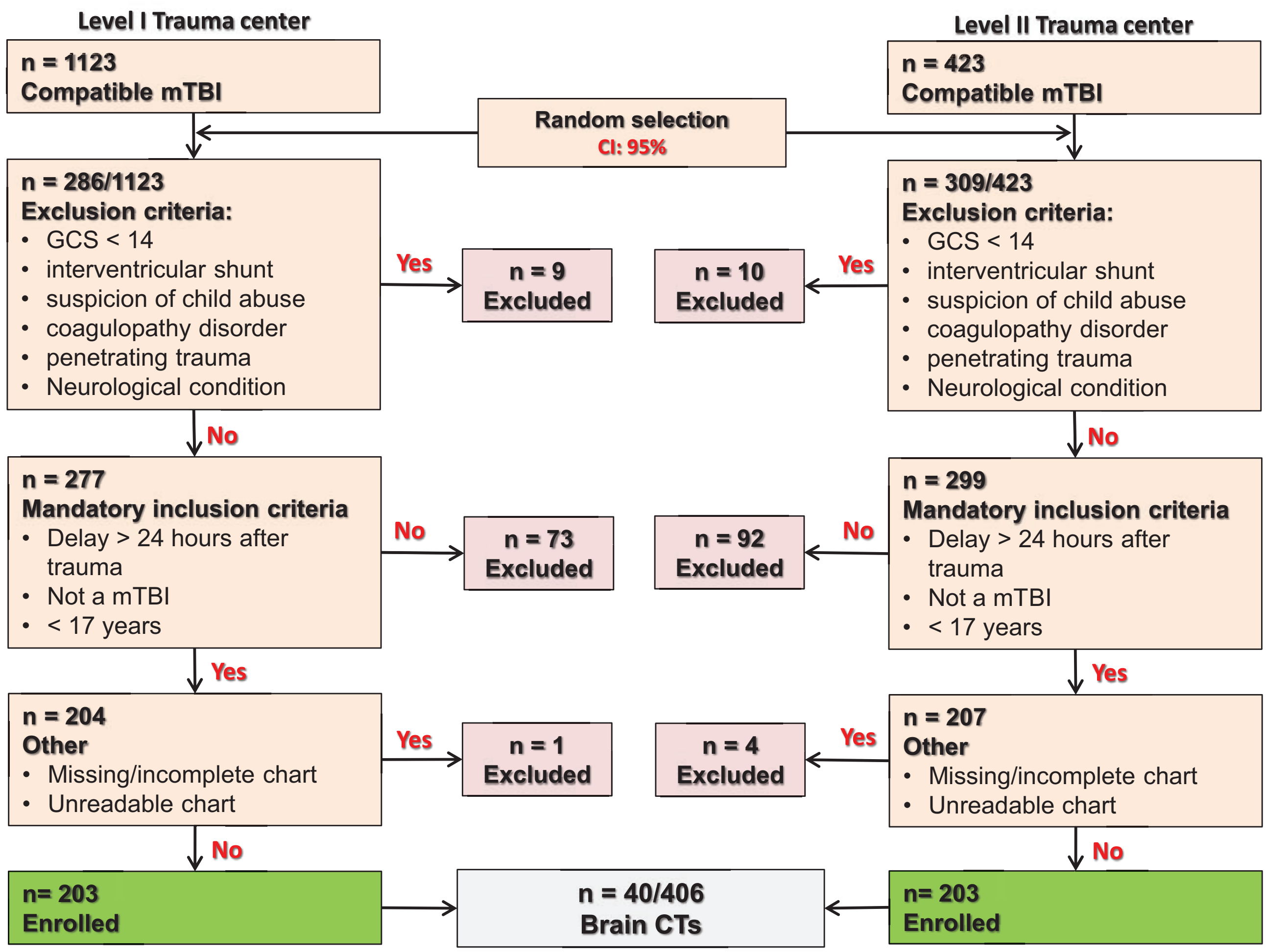

Figure 1. Patient selection flow diagram.

Of the 203 patients enrolled per setting, 54 from site 1 and 62 from site 2 were younger than 2 years (median 0.8; interquartile range [IQR] 0.5 to 1.2) and (median 0.8; IQR 0.5 to 1.3), respectively. Similarly, 149 from site 1 and 141 from site 2 were 2 years and older (median 13; IQR 9.5 to 15) (median 10; IQR 5.3 to 14), respectively. There were 131 male patients from site 1 and 109 from site 2 for a male/female ratio varying from 1:1 to 2:1. There were 112 from site 1 and 121 from site 2 who were classified as low risk, 75 from site 1 and 73 from site 2 as moderate risk, and 16 from site 1 and 9 from site 2 as high risk. A total of 16 (7.9%) patients from site 1 and 24 (12%) from site 2 underwent a head CT scan, and 6 (38%) scans from site 1 and 2 (8.3%) scans from site 2 were diagnosed abnormal according to a radiologist. For patients younger than 2 years old, the main mechanism of injury was a fall for both settings, varying from 92 to 93%. For the older group, the main mechanism of injury was also a fall for both settings, varying from 41 to 48%, followed by sporting injury from 31 to 36%. Other causes such as motor vehicle accident, assault, and other unspecified causes accounted for less than 10% for each setting. All baseline demographics are presented in Table 1.

Inter-rater reliability analysis

A total of 40 (14%) charts were reviewed by a second rater (JG) to assess inter-rater reliability. This duplicate evaluation reported a kappa score of 0.83 for identification of eligibility (inclusion/exclusion of patients) and a kappa score of 1.00 for risk assessment on the PECARN rule (low, moderate, or high risk) (Appendices 1 and 2, Supplementary material).

Risk assessment and head CT use

Table 2 presents the number of patients who received a head CT depending on their age group and risk assessment.

For the younger group, no child out of the 29 from site 1 and 1 child out of 35 from site 2 classified as low risk had a head CT scan, giving overuse rates of 0% (95% confidence interval [CI]: 0 to 12) and 2.9% (95% CI:0.5 to 15), respectively for site 1 and 2. On the other hand, all three patients at high risk from site 1 had a head CT scan. The distribution of children under 2 years of age as a function of risk classification is shown in Figure 2.

For the older group, 1 out of 83 children from site 1 and 8 out of 86 from site 2 classified as low risk had a head CT scan, giving an overuse rate of 1.2% (95% CI: 0.2 to 6.5) and 9.3% (95% CI: 4.8 to 17) for site 1 and 2, respectively, which gives a difference between the EDs of 8.1% (95Cl: 1.1 to 16%, P=0.03). There were 8 patients out of 13 from site 1 and 7 out of 9 from site 2 who had a head CT when classified as high risk, for a head CT rate of 62% (95% CI: 36 to 82%) for site 1 and 78% (95% CI: 45 to 94%) for site 2. The distribution of children belonging to the older category according to the risk assessment is shown in Figure 3.

No child categorized as high risk of ciTBI and who did not receive a head CT returned to the EDs under study within 30 days for a related complication.

DISCUSSION

The rate of head CTs for paediatric patients with signs and symptoms of mTBI varied from 7.9 to 12% in this retrospective

Table 1. Baseline demographics

Demographics	Level I		Level II	
	<2 years N=54	≥2 years N=149	<2 years N=62	≥2 years N=141
Median age, years (IQR)	0.8 (0.5–1.2)	13 (9.5–15)	0.8 (0.5–1.3)	10 (5.3–14)
Male, N (%)	31 (57)	100 (67)	31 (50)	78 (55)
Low risk, N (%)	29 (54)	83 (56)	35 (57)	86 (61)
Moderate risk, N (%)	22 (41)	53 (36)	27 (44)	46 (33)
High risk, N (%)	3 (5.6)	13 (8.7)	0 (0)	9 (6.4)
Head CT, N (%)	3 (5.6)	13 (8.7)	1 (1.6)	23 (16)
Abnormal dx, N (%)	1/3 (33)	5/13 (39)	1/1 (100)	1/23 (4.3)
Skull fracture	1/1 (100)	3/5 (60)	1/1 (100)	1/1 (100)
Cerebral contusion	-	1/5 (20)	-	-
ENT trauma	-	1/5 (20)	-	-
Mechanism of injury	**N (%)**	**N (%)**	**N (%)**	**N (%)**
Motor vehicle accident	0 (0)	4 (2.7)	1 (1.6)	11 (7.8)
Sport injury	0 (0)	54 (36)	0 (0)	44 (31)
Fall	50 (93)	71 (48)	57 (92)	58 (41)
Assault	0 (0)	6 (4.0)	0 (0)	4 (2.8)
Other	4 (7.4)	14 (9.4)	4 (6.4)	24 (17)

Table 2. Head CTs distribution as a function of age group and risk assessment

<2 years	Level 1 N (%)	95% CI	Level II N (%)	95% CI	Prop. diff. %	95% CI	P value
Low risk	0/29 (0)	0–12	1/35 (2.9)	0.5–15	2.9	-9.4–15	NS
Mod. risk	0/22 (0)	0–15	0/27 (0)	0–13	0	-13–15	NS
High risk	3/3 (100)	44–100	-	-	-	-	-
≥2 years							
Low risk	1/83(1.2)	0.2–6.5	8/86 (9.3)	4.8–17	8.1	1.1–16	0.03
Mod. risk	4/53 (7.6)	3.0–18	8/46 (17)	9.1–31	9.8	-3.4–24	0.22
High risk	8/13 (62)	36–82	7/9 (78)	45–94	16	-22–47	0.65

mod Moderate, underuse rate is the complement of the high-risk set; NS Nonsignificant; Prop. diff. Proportion difference.

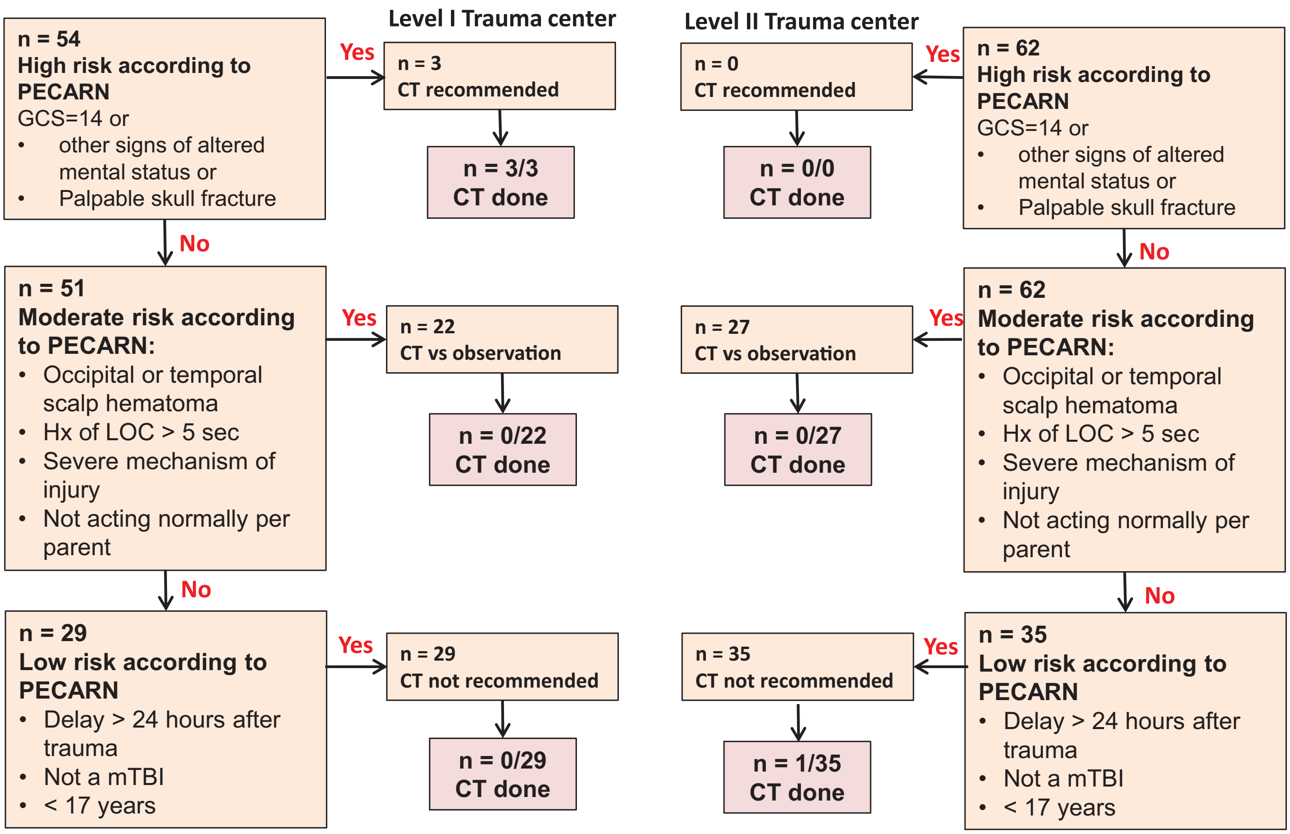

Figure 2. Population distribution for children under 2 years old according to their risk classification.

chart review of two Canadian EDs. For both EDs and notwithstanding age groups, overuse rates were below 10%, thus showing a medical practice in agreement with the generally accepted guidelines such as the PECARN rule.

Since the implementation of the PECARN rule, many studies have shown a decrease in the rate of head CTs for children with mTBI, varying 5.1 to 28% (15–20). This tendency was also noted in our study and can likely be explained by an increased concern for overusing head CTs in children. The study of Halaweish et al. (21) conducted in the USA was unique because it measured the net overuse rate of head CTs before and after the implementation of the PECARN rule. They showed that this rate varied from 20.7% pre- to 19.5% postimplementation, which led the authors to conclude to a poor compliance with the PECARN rule. However, only two studies computed the overuse rate using the PECARN rule: one from Italy in a tertiary trauma centre (19) and the other in a general hospital in Ireland (22). These studies agree with our results for the younger group, but showed scattered results for the older group, the overuse rate varying between 1.1 and 58%.

Overall, our research showed overuse rates which are much lower than available data in the literature. These results can

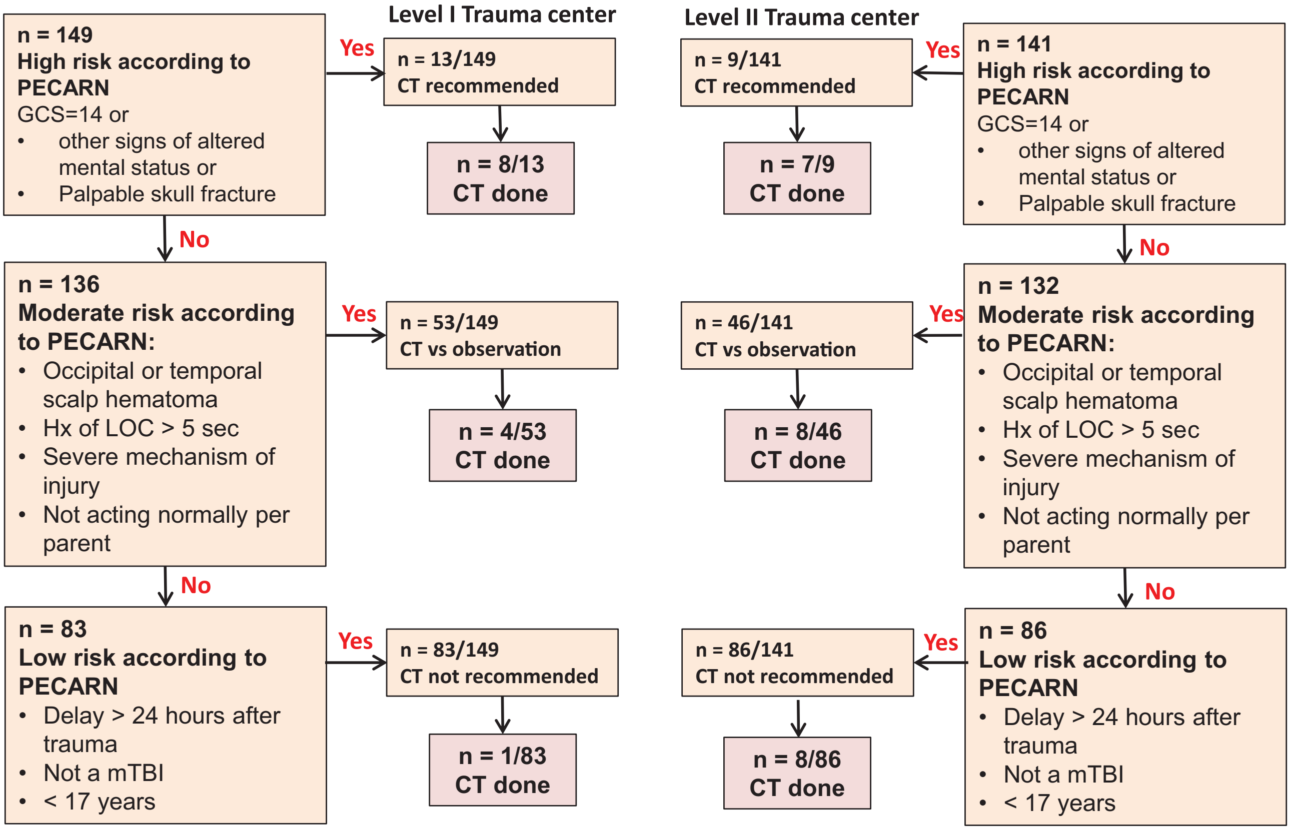

Figure 3. Population distribution for children 2 years and older according to their risk classification.

potentially be explained by the university affiliation of both hospitals. This hypothesis is in agreement with the results of Tama et al. (23) which showed that university hospitals had better adherence to the PECARN rule than nonuniversity ones. Another hypothesis could be the successful quality improvement campaigns led independently by the *Institut National d'Excellence en Santé et en Service Sociaux (INESSS)* since December 2011 (24) and *Choosing Wisely Canada* (25) since June 2015. These two organizations worked to raise awareness among physicians about the overuse of diagnostic tools and the dangers inherent to radiation. As an example, among many published recommendations in June 2015, the first one for Canadian emergency physicians is: "*do not order a head CT in children with mTBI unless positively validated with a clinical decision rule* (25)".

Surprisingly, this study has also shown a low head CT usage rate for high-risk patients, hence deviating from what is suggested by the PECARN rule. The reasons for this result are unclear. Perhaps the PECARN rule, despite its excellent sensitivity, is too strict in mandating head CTs in high-risk patients without allowing for ED observation as an alternative management strategy. However, more research is needed to fully understand the reasons of this behaviour.

LIMITATIONS

Owing to its retrospective design, our study was limited to the quality of information reported in the medical charts. Consequently, our reported rates must be considered with caution as we depended on the medical charts to determine if the PECARN criteria were being followed. To minimize the impact of this potential bias, triage nurses' notes, nurses' charted observations, physicians' medical notes, trauma assessments, specialist consultation reports, and radiologists' head CT results were consulted to gather as much information as possible. However, in the case of conflictual data, the physicians' notes were given priority. Moreover, the clinical outcome of discharged patients which did not receive a head CT when recommended was only verified in the same hospital they first visited and hence did not take into account the possibility that the patient could have consulted another ED. For this reason, we cannot make any safety assumptions about the potential underuse of head CTs we found for high-risk patients. Another limitation comes from the fact that we decided to use the PECARN rule to classify the risk of ciTBI and to define whether or not a head CT was recommended. Results could have been different if we had used another rule such as CATCH (26) or CHALICE (27). Finally, the fact that both trauma centres were teaching hospitals affiliated to two different universities within two urban areas in Canada limits the generalizability of this study's results. Future studies will have to be conducted to better document and understand the reasons for the potential variation in paediatric head CT use across EDs in Canada.

CONCLUSIONS

This study aimed to compute the overuse rate of head CT for paediatric patients with mTBI within two Canadian EDs: a level I paediatric trauma centre and a level II general trauma centre. Overall, even if there may be slightly more overuse of head CTs in the Level II trauma centre, results showed a good agreement with the PECARN rule. These results could be attributable to two organizations (INESSS and *Choosing Wiseley Canada*) which are working to raise awareness of the danger of excessive use of diagnostic tools.

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