

# PECARN rule in diagnostic process of pediatric patients with minor head trauma in emergency department

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## Research Article

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# Abstract

**Aim:** To evaluate the efficacy of the PECARN Rule (PR) in preventing the presence of clinically important traumatic brain (ciTBI).

**Methods:** A retrospective study was performed to our hospital between July 2015 and June 2020. Data of all children <18 years of age admitted to the Emergency Department (ED), within the 24 hours after a head trauma with GCS  $\geq 14$ , were analysed. PR was retrospectively applied to all patients

**Results:** 3832 patients were enrolled, 2613 patients  $\geq 2$  years and 1219 were younger. In the group of children  $\geq 2$  years, 10 presented ciTBI of which 7 underwent neurosurgery and 3 hospitalized. Applying the PR, no patient with ciTBI would have been discharged without a diagnosis. Between children <2 years, only 3 patients presented ciTBI, 2 underwent neurosurgery and 1 hospitalized. According the PR also in this age group no ciTBI would have been discharged without diagnosis.

**Conclusions:** We demonstrate the total effectiveness of the PR in our setting. We found 100% sensitivity in both age groups in identifying patients with ciTBI. Therefore, in patients classified in the low-risk category, it is a duty of the physician not to expose the child to ionizing radiation.

## Introduction

Head injury is the leading cause of death and disability in children and is also one of the most frequent reasons for admission to the pediatric Emergency Department (ED)[1]. However, more than 90 % of these traumas are minor head injuries (MHI), that are not associated with brain injury or long-term sequelae in children [2-3]. Only a small number of pediatric patients who experience MHI may still have a clinically important traumatic brain injury (ciTBI) [4]. CT scan is the gold standard for the evaluation and management of patients with any type of head trauma; it is highly sensitive in identifying clinically significant brain lesions that require acute intervention [5]. The clinical challenge in evaluating minor TBI in pediatric patients is identifying those children with ciTBI. This would limit unnecessary exposure to carcinogenic ionizing radiation, the need for sedation for uncooperative children and the associated cost.

The PECARN rule (PR) is a very simple to apply decision rule and it has proven to be the most sensitive in identifying ciTBIs [6].

## Patients And Methods

We performed a retrospective observational study of children with MHI admitted to the ED of A. Gemelli hospital in Rome, with annual attendance of about 13.000 patients younger than 18 years of age. The study was conducted between July 2015 and June 2020. We included children less than 18 years of age who presented to the ED within the 24 hours after a head trauma with an initial GCS  $\geq 14$ . We applied the mHT PR<sup>6</sup> to all children enrolled distinguishing two subpopulations of children over and under two years old as required by the rule. Therefore, we distinguished patients according to the three categories of

recommendations of the PR: recommended CT scan, CT scan versus observation, and CT scan to be avoided (Figure 1).

We excluded children with severe head trauma; those with trauma that occurred more than 24 hours before the emergency room visit; patients who have neuroimaging in another hospital or have only come for counselling from another hospital; patients who did not wait for the visit or refused clinical observation; patients who lacked the necessary data for the application of the PR.

The main aim of the study was to evaluate the efficacy of the PR in preventing the presence of ciTBI. Secondary objective was to predict, with the PR, the incidence of ciTBI and/or fractures on CT scan even if not clinically important, in patients who performed a CT scan of the skull.

Patients were identified from the hospital computerized clinical record (GIPSE®) by searching for the keywords "head injury", "concussion", "head trauma", "road injury" for all patients admitted to the ED.

Clinical and demographic data were collected by paediatric specialists after being trained in a data collection form developed specifically for the study. (Table1)

For children undergoing brain CT we also analyzed: any visible lesion involving the brain or the skull; neurosurgery need; hospitalization time in days; site of the head injury. Then we retrospectively applied the PR to all enrolled children. This study was approved by the Institutional Review Board and Ethic Committee of our institution.

Categorical variables are reported as percentages. Continuous variables are described using medians and interquartile ranges (IQR). We performed comparisons between groups by means of Chi-squared tests for categorical variables. Parameters displaying  $p < 0.05$  were considered statistically significant. Sensitivity, specificity and ROC area under curve (AUC) are presented as value (95% confidence interval). We performed multivariate logistic regression models including variables with a  $p$ -value  $< 0.05$  in the univariate analysis.

## Results

During the study period, the medical records of 4943 patients were retrospectively analyzed. We considered 3832 patients eligible for the study (mean age 5.3 years, SD 4.8). 2613 patients were  $\geq 2$  years, while 1219 were younger. 551 patients (14.4%) underwent CT examination, of which 96 were younger than 2 years (17.4%) and 455 (82.6%) were age  $\geq 2$  years (median age 10, 99 years; 25th percentile = 5.78; 75th percentile = 14.35). (Figure 2). All the characteristics of the study population are summarized in Table 1.

We first examined the group of **children  $\geq 2$  years**, with a median age of 6,015 (IQR 3.44-10.73).

907 patients received frontal trauma (34.71%), 293 parietal (11.21%), 161 temporal (6.16%), 623 occipital (23.84%), 161 facial trauma (6.16%) and in approximately 689 cases it was not possible to identify a site

of the trauma.

Applying the PR, we observed that for 30 children (1.15%) the CT scan was recommended and 29 of these performed it (96.7%). The PR recommended clinical observation for 653 of these patients (25%). Of these 286 performed a head CT scan (43.8%). CT scan was instead to be avoided according to the PR in 1930 patients (73.85%), but 140 patients underwent head CT scan in this risk category (7.26%).

In this age group, 10 patients presented ciTBI of which 7 underwent neurosurgery and 3 hospitalized over two nights. (Table 1)

The PR assigned 2 of the patients undergoing surgery to the group "CT scan recommended", while the other 5 were classified in the "CT scan versus observation" group and all presented clinical deterioration within the first hours of observation.

Regarding the 3 hospitalized patients with ciTBI, according PR 2 were classified as a "CT scan recommended" group, and 1 was part of the "CT scan versus observation" group but, within the first hours of observation, he developed marked sleepiness.

Therefore, applying the PR, no patient with ciTBI would have been discharged without a diagnosis, with a sensitivity of 100%.

455 patients (17.41%) underwent head CT scans of which 40 were abnormal.

Among the 34 patients with CT scan alterations considered by the rule belonging to the "CT scan versus observation" group, 28 had a fracture (of which 10 were multiple), 4 had subarachnoid haemorrhage and 2 subdural hematomas. 5 patients with CT scan alterations were considered by the PR to be "at high risk", 4 had skull fractures and 1 had a left temporal parenchymal hematoma with intraventricular haemorrhage from post-traumatic rupture of arteriovenous malformation.

Only 1 patient with CT scan changes, considered by the PR "at low risk", had a subarachnoid haemorrhage in the left frontal area, that did not require neurosurgery.

Besides the statistical correlation between the PECARN recommendation categories and the presence of CT scan changes was statistically significant ( $p = 0.000$ ).

We then carried out in this population a detailed analysis of the variables considered by the PR, and we analysed them individually and after multivariate analysis.

We confirmed that presenting episodes of repeated vomiting (OR: 6.0, CI: 1.2–6.3), a severe mechanism of trauma (OR: 3.4, CI: 1.6-7.1), receiving trauma in the parietal site (OR: 2.8, CI: 1.2 –6.3) and in the occipital site (OR: 2.1, CI: 1.0–4.3) remain to be independently associated with the presence of alterations at head CT scan.

The analysis of the ROC curves of the PR showed a sensitivity of 97.5% (CI 86.8% - 99.9%) in identifying patients with CT scan alterations and a specificity of 33, 5% (CI 29% - 38.3). (Figure 3)

In the subpopulation of 1219 **patients <2 years** enrolled in the study the median age was 0.99 years (IQR 0.63-1.39).

477 patients received frontal trauma (39.1%), 126 parietal (10.3%), 56 temporal (4.6%), 151 occipital (12.4%), 36 facial trauma (3%) and in approximately 441 cases it was not possible to identify a site of the trauma.

According to the PR, for 17 children (1.4%) CT scan was recommended and 16 performed it (94%). The PR recommended clinical observation for 358 patients (29.4%), of these 56 performed a head CT scan (15.6%). CT scan was instead to be avoided in 844 patients (69.20%) but 24 underwent head ct scan in this risk category (2.84%).

In the group of children <2 years only 3 patients presented ciTBI, 2 underwent neurosurgery and 1 hospitalized more than two nights. The PR assigned one of the patients undergoing surgery to the group "CT scan recommended" and the other in the "CT scan versus observation" group. The latter, few minutes after the start of clinical observation, developed profound drowsiness and CT showed an epidural hematoma. The last child with ciTBI in this age group, classified in the "CT scan versus observation" group, presented clinical worsening and irritability for which he performed an intensive observation in PICU and prolonged hospitalization. Therefore, applying the PR also in this age group, no ciTBI would have been discharged without diagnosis with a sensitivity of 100%.

96 patients (7.86%) underwent head CT scans of which 49 were abnormal.

Among the 40 patients with CT scan alterations considered by the rule belonging to the "CT scan versus observation" group, 39 had a fracture (of which 12 were multiple), while the only 1 presented an isolated left frontal subarachnoid hemorrhage.

All the 8 patients with CT alterations, considered by the PR to be "at high risk", presented skull fractures of which 5 were parietal, 1 occipital and 2 multiples.

Also in this age group the statistical correlation between the PECARN recommendation categories and the presence of CT scan changes was statistically significant ( $p = 0.000$ ).

Instead, only the younger age at the moment of trauma is independently associated with CT scan alterations at the multivariate analysis.

In children under 2 years, the analysis of the ROC curves of the PR showed a sensitivity of 97.96% (CI 89.1% - 99.9%) in identifying patients with CT scan alterations and a specificity of 48.94% (CI 34.1% - 63.9%). (Figure 4)

## Discussion

Our study performed in an Italian pediatric population, confirmed that PR have good accuracy in identifying children with MHI. CT scan is the gold standard for the evaluation of patients with any type of head trauma but it exposes children to carcinogenic ionizing radiation. Although the effective dose for head CT is relatively low, the brain and red bone marrow doses are relatively high, especially in young children, resulting in the highest risks of brain cancer and leukemia [7-8].

In literature, different authors proposed clinical algorithms for evaluating pediatric patients with MHI but the PR seem to have the best methodological quality [6, 9-10].

The retrospective application of the PR in our study, showed a sensitivity of 100% in identifying patients with ciTBI in both age groups and very high negative predictive values identifying patients as low risk, confirming the data already reported by other authors.

In our cohort of 3832 patients with MHI, only 13 had a ciTBI. In 4 of these patients, the rule recommended an immediate CT scan. None of the remaining patients belonged to the low-risk group.

We then performed a subgroup analysis of patients who underwent CT scans following MHI.

In our analysis, the statistical correlation between PECARN risk categories and the presence of fractures and/or intracranial lesions is statistically significant in both subgroups ( $p = 0.000$ ).

According to PR, one patient for each of the two age groups, having no clinical predictor of high risk for ciTBI, would therefore be discharged.

However, this would not have had any consequences on the patients' outcome since they did not require neurosurgery, nor did they have complications.

The analysis of sensitivity and specificity confirms the PR as an excellent clinical algorithm in identifying also patients with fracture or traumatic brain injury even if not clinically important. In fact, sensitivity evaluated in our study was 97.5% over two years and 97.96 under two years.

This gives clinicians a relatively high confidence in discriminating against patients who are truly at risk of serious clinical events following the trauma.

Despite the relatively low rate of acquired CT scans in our ED, similar to other Italian [11] or American [12] centers, applying the PR rigorously to all patients we would have avoid 139 head CT scans in patients 2 years of age or older, and 23 head CT scans in those under 2 years of age (equal to 29% less).

This would have reduced exposure to ionizing radiation while maintaining a high sensitivity for clinically-important traumatic brain injury. This considering only patients in the "no CT scan" group according to the PR.

However, even in the "CT scan versus observation" group, the PR proved to be a useful tool. In fact, in this group ED physicians should favor initial observation over CT scan, especially in the presence of isolated findings, no worsening of symptoms and a child older than 3 months. Indeed, our results confirm these indications because all 9 patients with ciTBI in this risk category, had worsening of symptoms during clinical observation [13].

This is also confirmed by a secondary analysis of the PECARN head injury parent study which showed that clinical observation before CT decision making resulted in a safe and potentially effective strategy to manage a subset of children with MHI.

Finally, we found from the multivariate analysis that vomiting showed a significant correlation with an abnormal CT scan. Vomiting is a frequent sign in children with head trauma (more than 20% of patients undergoing CT). Since our statistical analysis does not consider the number of episodes, we cannot consider this isolated sign as indicative of the presence of lesions in the CT scan, as already claimed by other authors [12-14].

In the population aged <2 years, the only variable significantly correlated with positive CT was age, with an increased risk of having fracture or brain injury on CT as it decreases (p-value = 0.02).

The study has some limitations. First of all, some patients were excluded from the study because their parents refused observation in the ED or because there was a lack of data necessary for the calculation of the PR. However, we can postulate that they were consistently distributed across the various PECARN risk categories without affecting the results.

Furthermore, among the patients who have not performed the CT scan, some may have fractures or intracranial injuries even if they do not need surgery. If these patients were hospitalized for more than two nights, the number of ciTBIs in our study would change. To overcome this problem, we have analyzed only patients who have performed the CT scan demonstrating a wide range of patients in which CT can be avoided safely.

Another limitation of the study is not having recalled patients to find out if the enrolled children had performed a second visit to another hospital for ciTBI. However, we believe this is unlikely to happen considering that the emergency room doctor instructs parents to return when the first symptoms appear.

The strengths of our study lie in a large number of patients enrolled and in the analysis of the individual items of the PR individually. In fact, we can consider the parietal site and a severe mechanism of trauma as two red flags to be carefully considered in the age group over two years. On the other hand, under the age of two, attention needs to be increased particularly in younger children, as indeed underlined by the rule.

The PR is already considered a useful and safe tool for the management of MHI in the ED, we have demonstrated the total effectiveness of the rule in the ED of our setting. We found 100% sensitivity in

both age groups in identifying patients with ciTBI. Therefore, in patients classified in the low-risk category, it is a duty of the physician not to expose the child to ionizing radiation.

Furthermore, analysing the subpopulation of patients who have performed the CT scan, the rule has proved extremely sensitive even in identifying patients with fractures or TBI even if not clinically important.

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## Tables

Characteristics	Study Choort (N=3832)	<2 years (N=1219)	≥ 2 years (N=2613)
<b>Median Age (years)</b>	5.3 (SD 4.8)	0.99 years (IQR 0.63-1.39)	6.01 (IQR 3.44-10.73)
<b>Gender (Male)</b>	2381 (65.13 %)	665 (54.6%)	1716 (65.6%)
<b>Time in PED (hours)</b>	2.42 (IQR 1.15-3.78)	2.43 (IQR 1.27-3.62)	2.4 (IQR 1.30-3.83)
<b>Re-visit in ED</b>	46 (1.2%)	12 (0.98%)	34 (1.3%)
<b>Triage color code</b>			
<b>Red</b>	47 (1.2%)	2 (0.17%)	45 (1.72%)
<b>Yellow</b>	726 (19%)	203 (16.65%)	523 (20.02%)
<b>Green</b>	3059 (79.8%)	1014 (83.18%)	2045 (78.26 %)
<b>Trauma site</b>			
<b>Frontal</b>	1384 (36.1%)	477 (39.1%)	907 (34.7%)
<b>Parietal</b>	419 (10.9 %)	126 (10.3%)	293 (11.2%)
<b>Temporal</b>	217 (5.7%)	56 (4.6%)	161 (6.16%)
<b>Occipital</b>	774 (20.2 %)	151 (12.4%)	623 (23.8%)
<b>Facial</b>	197 (5.1%)	36 (3%)	161 (6.2%)
<b>Unknown</b>	1130 (29.5 %)	441 (36.2%)	689 (26.4%)
<b>Transportation</b>			
<b>Ambulance</b>	586 (15.3%)	110 (9%)	476 (18.2%)
<b>Helicopter rescue</b>	30 (0.8%)	8 (0.7%)	22 (0.8%)
<b>Own vehicles</b>	3216 (83.9%)	1101 (90.3%)	2115 (81.0%)
<b>Mechanism of Injury</b>			
<b>Domestic Injury</b>	1834 (47.9%)	895 (73.4%)	939 (35.9%)
<b>Motor vehicle accident</b>	331 (8.6%)	46 (3.8%)	285 (10.9%)
<b>School accident</b>	368 (9.6%)	27 (2.2%)	341 (13.1%)
<b>Sports-related</b>	198 (5.1%)	0	198 (7.6%)
<b>Aggression</b>	23 (0.6%)	0	23 (0.9%)
<b>Other accidents</b>	643 (16.8%)	135 (11.1%)	508 (19.4%)
<b>Undefined</b>	435 (11.4%)	116 (9.5%)	319 (12.2%)

<b>Destination</b>			
<b>Discharged at home</b>	3680 (96%)	1168 (95.8%)	2512 (96.1%)
<b>Hospitalization</b>	152 (4%)	51 (4.2%)	101 (3.9%)
<b>CT</b>	541 (14.11 %)	96 (7.86%)	455 (17.41%)
<b>Observation</b>	145 (3.78 %)	40 (4.0%)	105 (4.0%)
<b>ciTBI</b>	13 (0.34 %)	3 (0.24 %)	10 (0.38%)
<b>Neurosurgical intervention</b>	9 (0.23 %)	2 (0.16 %)	7 (0.27 %)

Table 1

## Figures

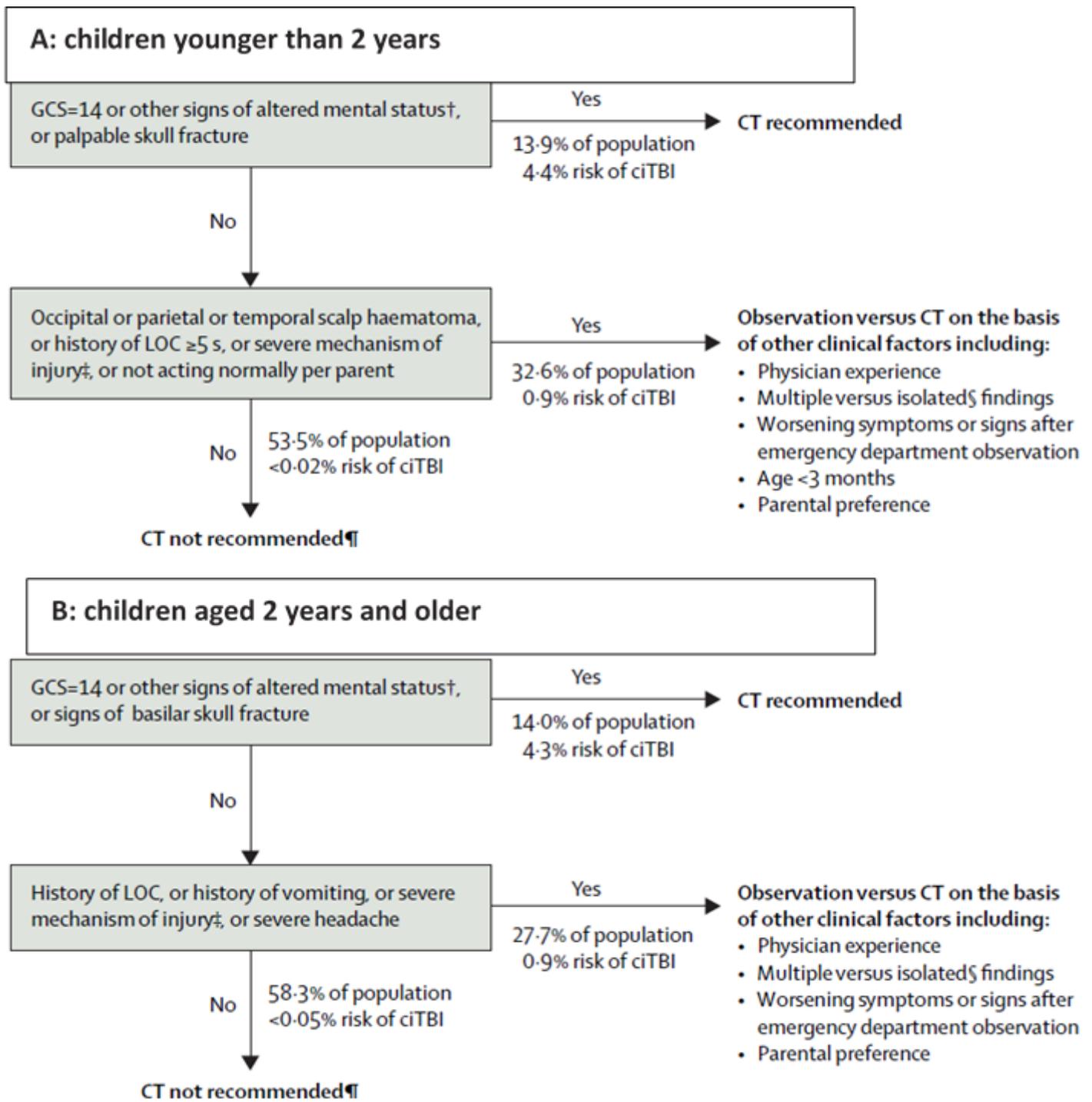
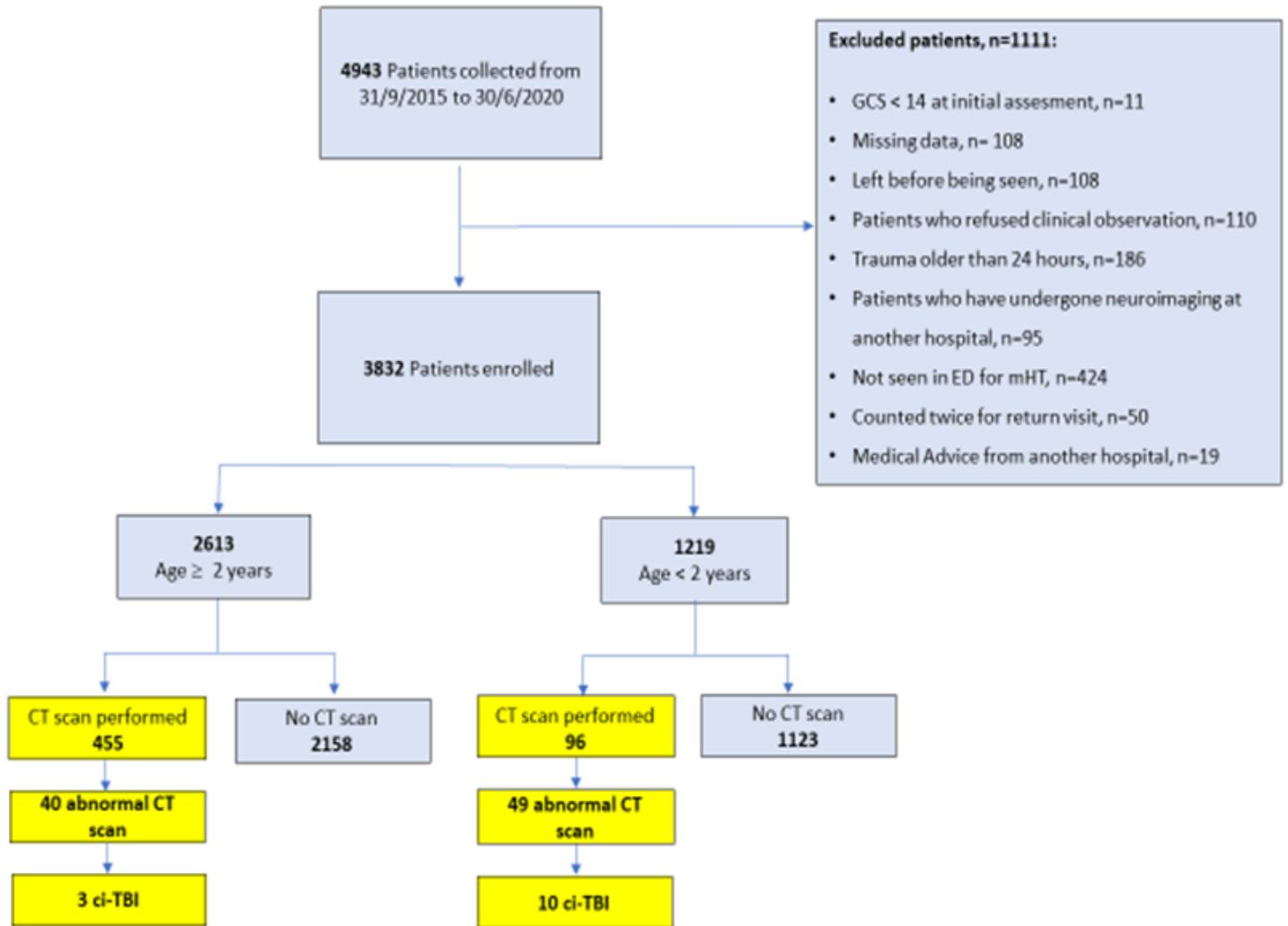


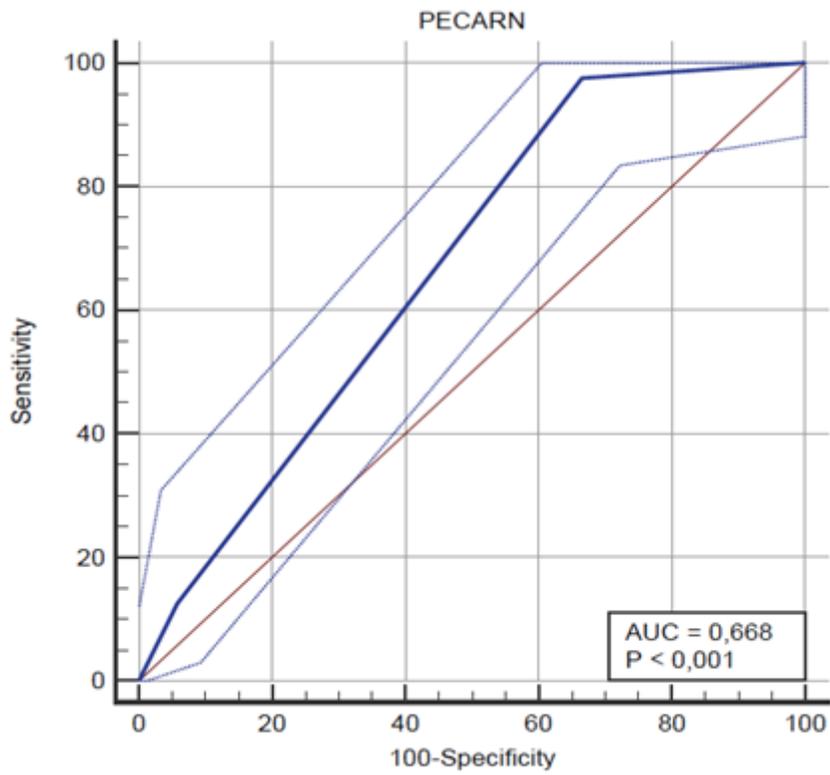
Figure 1

Categories of recommendations according to the PECARN Rule.



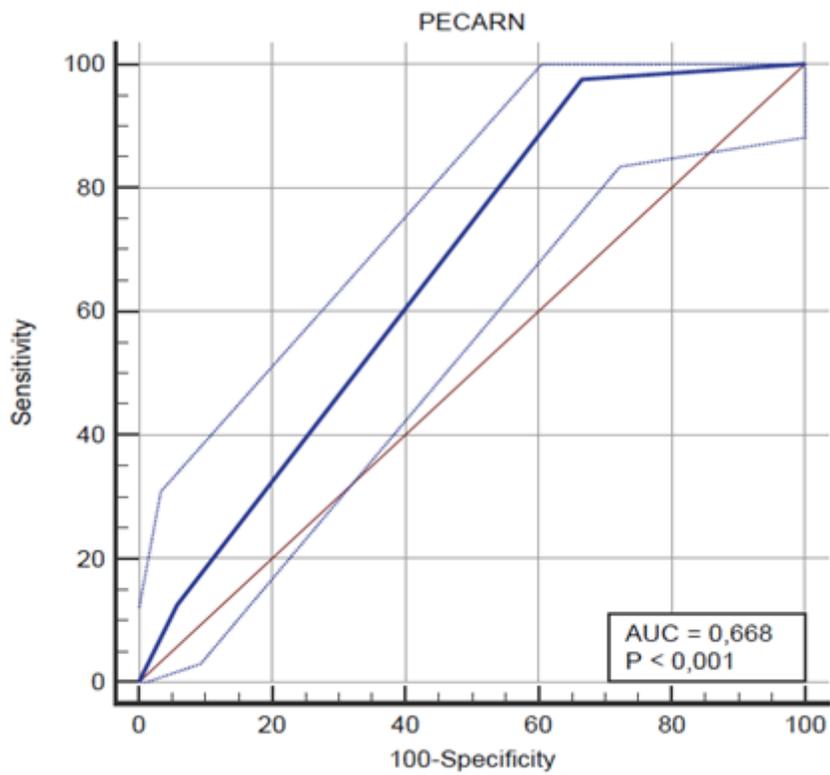
**Figure 2**

Flow chart of study



**Figure 3**

The ROC curve shows the specificity and sensitivity of the PECARN Rule in identifying children  $\geq 2$  years with CT scan alterations



**Figure 4**

The ROC curve shows the specificity and sensitivity of the PECARN Rule in identifying children under 2 years with CT scan alterations