SEUP SOCIEDAD ESPAÑOLA DE URGENCIAS DE PEDIATRÍA

EMERGENCIASPediátricas
Vol. 5. No. 3

Sociedad Latinoamericana de Emergencias Pediátricas SLEPE

Emergencias Pediátricas. 2026; 5(3): –

ORIGINAL ARTICLE

Validation of the predictive capacity of the pediatric trauma index in children under 12 years of age

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Received February 15, 2026
Accepted May 14, 2026
Published November 20, 2026

Keywords:
Pediatric trauma
Pediatric Trauma Index
Prediction scales
Severity
Validation

Palabras clave:
Trauma pediátrico
Índice de trauma pediátrico
Escalas de predicción
Severidad
Validación

Abstract

Pediatric trauma is a significant public health problem and one of the leading causes of emergency department visits and childhood mortality worldwide. Accurate risk stratification using validated triage tools, such as the Pediatric Trauma Index (PTI), is essential for optimizing care, particularly in high-demand settings. This study validated the predictive performance of the PTI in a prospective cohort of 470 children under 12 years of age treated for trauma at a tertiary-care hospital in Colombia. Outcomes assessed included clinical severity, hospitalization, prolonged length of stay, surgery, admission to the pediatric intensive care unit (PICU), and sequelae. The results show that the PTI has high specificity and an excellent negative predictive value for ruling out severe outcomes, with particularly strong performance in predicting clinical severity (sensitivity: 90.9%, specificity: 96.3%, NPV: 99.8%, LR+: 24.5, kappa: 0.51, AUROC: 0.97) and the presence of sequelae (sensitivity: 71.4%, specificity: 96.3%, NPV: 99.1%, LR+: 19.2, kappa: 0.47, AUROC: 0.93). The PTI cutoff of ≤ 6 demonstrated superior diagnostic performance. We conclude that the PTI is a valuable and reliable tool for ruling out complications during the initial triage of pediatric patients.

VALIDACIÓN DE LA CAPACIDAD PREDICTIVA DEL ÍNDICE DE TRAUMA PEDIÁTRICO EN MENORES DE 12 AÑOS

Resumen

El trauma pediátrico representa un significativo problema de salud pública, siendo una de las principales causas de consulta en servicios de urgencias y de mortalidad infantil a nivel mundial. La correcta estratificación del riesgo mediante herramientas de triaje validadas, como el Índice de Trauma Pediátrico (ITP), es fundamental para optimizar la atención, especialmente en contextos de alta demanda. Este estudio validó la capacidad predictiva del ITP en una cohorte

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prospectiva de 470 niños menores de 12 años atendidos por trauma en un hospital de alta complejidad en Colombia. Se evaluaron desenlaces como severidad clínica, hospitalización, estancia prolongada, cirugía, ingreso a UCIP y secuelas. Los resultados demuestran que el ITP posee una alta especificidad y un excelente valor predictivo negativo para descartar desenlaces graves, destacando su rendimiento para predecir severidad clínica (S: 90,9%, E: 96,3%, VPN: 99,8%, LR+: 24,5, Kappa: 0,51, AUROC: 0,97) y la presencia de secuelas (S: 71,4%, E: 96,3%, VPN: 99,1%, LR+: 19,2, Kappa: 0,47, AUROC: 0,93). El punto de corte ITP ≤ 6 exhibió un rendimiento diagnóstico superior. Se concluye que el ITP es una herramienta valiosa y fiable para el descarte de complicaciones en el triaje inicial de pacientes pediátricos.

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INTRODUCTION

Trauma is the leading cause of morbidity and mortality in the pediatric population across diverse regions, resulting in more years of life lost before age 18 than cancer, sudden death, and infectious diseases combined[1–3]. In Latin America, this phenomenon is particularly acute, with injury-related mortality rates exceeding those in high-income regions, reflecting disparities in road infrastructure, safety, and access to health care systems[3,4]. This epidemiological burden underscores the critical need to optimize trauma care systems for this vulnerable population.

Children have anatomical and physiological characteristics that result in injury patterns and responses to trauma that differ from those of adults. Proportionally, the head is larger and the cervical muscle support is weaker, increasing the risk of traumatic brain injury (TBI), the most frequent and severe injury in this age group. Likewise, the greater elasticity of the thoracic cage and the less effective muscular protection of the abdominal organs make children more susceptible to significant internal injuries, even in the absence of fractures. Physiologically, children have a remarkable capacity for hemodynamic compensation and may maintain blood pressure until advanced stages of shock, potentially masking the true severity of the injury and delaying critical interventions[5].

Against this backdrop, trauma severity scales have become established as objective and indispensable tools for standardizing *triage*, predicting outcomes, and continuously improving the quality of care. These scoring systems translate injury severity into a numerical value, facilitating standardized communication among professionals and comparison of outcomes across different centers—an essential practice for auditing and improving trauma systems[6–8].

The Pediatric Trauma Index (PTI), also known as the *Pediatric Trauma Score*, was developed by Tepas et al. in 1987 specifically for the pediatric population[9]. This index evaluates six key components: weight, airway status, systolic blood pressure (SBP), central nervous system (CNS) status, presence of open wounds, and skeletal fractures. Each component is scored as +2 (normal), +1 (minor impairment), or -1 (severe impairment), yielding a total score ranging from -6 (maximum severity) to +12 (minimum severity)[6,9,10].

The PTI has been validated in multiple international studies (Table 1), which have confirmed its high specificity and NPV—although sensitivity and PPV have varied—in predicting hospitalization and the need for critical interventions for nearly four decades[7–20]. Its ease of use, together with these findings, keeps the PTI relevant as a reference tool for the initial assessment of pediatric trauma, despite the development of other predictive scales that are more accurate for certain outcomes.

TABLE 1. Studies on the predictive capacity of the Pediatric Trauma Index (PTI)*

Study	Year	Country (Region)	N	PTI (cutoff)	Se (%)	Sp (%)	PPV (%)	NPV (%)
Tepas et al	1987	United States (Jacksonville)	230	≤ 6	96	99	98	97
Ramenofsky et al	1988	United States (Seattle)	450	≤ 8	96	99	96	99
Eichelberg et al	1989	United States (Seattle)	1334	≤ 8	78	75	33	95
Aprahamian et al	1990	United States (Seattle)	144	≤ 8	71 - 75	90	48	-
Kaufmann et al	1990	United States (Seattle)	376	≤ 8	-	50	13	100
Narci et al	2008	Turkey (Afyon)	74	≤ 8	-	-	-	-
Wilches et al	2011	Colombia (Bogotá)	81	≤ 8	-	-	-	-

Study	Year	Country (Region)	N	PTI (cutoff)	Se (%)	Sp (%)	PPV (%)	NPV (%)
Fieber et al	2014	United States (New Haven)	3816	≤ 10	56	75	-	-
Essa et al	2017	Egypt (Ismailia)	60	≤ 8	96	99	-	-
Anil et al	2017	Turkey (Istanbul)	213	≤ 8	56	91	-	-
Sultanoglu et al	2019	Turkey (Gaziantep)	1510	≤ 8	75	83	-	-
Wendling et al	2021	Turkey (Ankara)	97	≤ 8	-	-	-	-
De los Ríos et al	2022	Colombia (Cali)	1047	≤ 8	-	-	-	-
Misirlioglu et al	2024	Turkey (Mersin)	176	≤ 8	59	96	93	70

*For hospitalization and/or need for PICU/critical interventions**

In Colombia, research on the performance of the PTI is limited. A recent study conducted in Cali evaluated the PTI in a cohort of 1,047 patients under 18 years of age. Conducted in a context of high interpersonal violence, the study found a high prevalence of penetrating firearm injuries among adolescents and a mortality rate of 5.9%. In this population, the PTI demonstrated excellent ability to predict mortality (AUROC: 0.93)[13]. However, the epidemiology of trauma in younger children and in other regions of the country, where low-energy mechanisms such as falls predominate, is markedly different.

This study was designed to address this knowledge gap by validating the predictive ability of the Pediatric Trauma Index for a range of relevant hospital outcomes (severity, need for interventions, sequelae) in a population of children under 12 years of age treated at a referral center in Bucaramanga, Colombia, characterized by a high incidence of blunt trauma.

METHODOLOGY

An observational, prospective prognostic technology evaluation study was conducted to determine the ability of the Pediatric Trauma Index (PTI) to predict hospital outcomes in pediatric patients.

The study was conducted in the pediatric emergency department of the Hospital Universitario de Santander (HUS) in Bucaramanga, a high-complexity center that serves as a referral center for the region.

The sample size was calculated to detect differences in mortality (1% for PTI ≤ 8 vs. 0.2% for PTI > 8, prevalence 30%), with 80% power and α = 0.05 (n = 696). Of 585 cases recruited (Aug 2020–Nov 2021), 470 were analyzed after excluding 115 (19.7%): incomplete PTI data (n = 42), no outcome data (n = 38), consent/selection errors (n = 25), and transfers (n = 10).

All cases presenting with trauma of mechanical origin, with no association with other injury mechanisms (e.g., burns, drowning, poisoning) or domestic violence, were enrolled consecutively.

At the time of enrollment, the PTI was scored based on the initial medical record. The six components of the scale were defined as presented in Table 2.

TABLE 2. Components and scoring of the Pediatric Trauma Index (PTI)

Component	Category (+2)	Category (+1)	Category (-1)
Weight	> 20 kg	10–20 kg	< 10 kg
Airway	Normal	Maintainable	Unmaintainable
SBP	Palpable radial pulse	Palpable femoral pulse	Absent pulse
CNS	Alert	Drowsy/stuporous	Superficial/deep coma
Wounds	No	Minor	Major or penetrating
Fractures	No	Closed	Open or multiple

Each component is scored as +2 (best prognosis), +1 (intermediate), or -1 (worst prognosis). The total score ranges from -6 to +12. A PTI ≤ 6 is usually associated with a higher risk of adverse outcomes.

The primary outcome variables, collected during the hospital stay, were: clinical severity (classified as mild, moderate, or severe by the treating clinical team of orthopedic surgeons, plastic surgeons, neurosurgeons, and/or pediatric surgeons, based on ATLS guidelines), hospitalization, prolonged stay (more than 7 days), need for surgery (major or minor), PICU admission, need for Cardiopulmonary Resuscitation (CPR), and sequelae at discharge (permanent disability or loss of an organ/limb, also assessed by the treating team).

A descriptive analysis of the cohort was performed using STATA v16 (quantitative variables: medians/IQR, Shapiro–Francia test; qualitative variables: frequencies/percentages). Validation of the PTI included sensitivity, specificity, PPV, NPV, and LR± (95% Wilson score CI with continuity correction for rare events: PICU 0.6%, CPR 0.2%), Cohen's kappa agreement (95% CI, bootstrap with 1,000 replications), and AUROC (nonparametric method using the trapezoidal rule / Mann–Whitney U test and DeLong test to calculate the 95% CI and standard error) for PTI ≤ 8 vs. ≤ 6, with k = 5 cross-validation. Intra-/interobserver reliability was assessed using a convenience sample: the first 30 cases plus every 5th case (n = 106). Three observers were used [emergency pediatrician + 2 physician researchers], conducting interobserver analysis (independent, anonymized PTI scoring with mutual blinding) and intraobserver analysis (reassessment 4 weeks later, recoded and with prior blinding). Quadratic weighted kappa (continuous) and unweighted kappa (PTI ≤ 8) were calculated.

Approval was obtained from the Scientific Research Ethics Committee of the Industrial University of Santander (CEINCI-UIS) and the Research Ethics Committee of the Santander University Hospital (CEI-HUS). Written informed consent was obtained from the legal representative of each participant and, when applicable (for children older than 7 years), the patient's assent.

RESULTS

Among the children's general characteristics, the cohort's median age was 70 months (IQR: 42–100 months), with a clear predominance of males (n = 292; 61.9%). The most frequent injury mechanism was a fall (n = 334; 71%), followed by blows and traffic accidents (13% each). The distribution of PTI scores showed a median of 10 (IQR: 9–11), with 27 cases with PTI ≤ 8 (6%) vs. 443 with PTI > 8 (94%). Clinical outcomes by group were: hospitalization, 21/27 (78%) with PTI ≤ 8 vs. 143/443 (32%) with PTI > 8; surgery, 18/27 (67%) with PTI ≤ 8 vs. 137/443 (31%) with PTI > 8; prolonged stay (> 7 days), 15/27 (55.6%) with PTI ≤ 8 vs. 48/443 (10.8%) with PTI > 8; PICU admission, 1/27 (4%) with PTI ≤ 8 vs. 2/443 (0.5%) with PTI > 8; sequelae, 10/27 (37%) with PTI ≤ 8 vs. 4/443 (0.9%) with PTI > 8; no deaths occurred in either group.

Evaluation of the traditional PTI cutoff (≤ 8) demonstrated robust diagnostic performance, particularly for ruling out adverse outcomes, as detailed in Table 3.

TABLE 3. Diagnostic performance of the PTI at a cutoff of ≤ 8

Outcome	Prevalence (%)	Sensitivity% (95% CI)	Specificity% (95% CI)	PPV % (95% CI)	NPV % (95% CI)	LR+ (95% CI)	LR- (95% CI)	AUROC (95% CI)
Moderate severity	42.8	11.9 (5.9-21.0)	98.9 (97.3-99.8)	88.9 (65.3-96.9)	60.0 (57.1-62.9)	10.7 (2.8-40.7)	0.9 (0.8-1.0)	**0.61 (0.56-0.66)**
High severity	2.3	90.9 (65.2-98.6)	96.3 (94.1-97.9)	37.0 (23.2-53.0)	99.8 (98.7-99.9)	24.5 (14.1-42.5)	0.1 (0.0-0.4)	**0.97 (0.95-1.00)**
Hospitalization	34.9	12.8 (8.9-17.6)	98.7 (97.0-99.6)	77.8 (60.1-89.3)	75.6 (72.4-78.6)	9.6 (4.1-22.4)	0.9 (0.8-0.99)	**0.61 (0.56-0.67)**
Length of stay >7 days	13.4	40.9 (27.0-55.8)	96.0 (93.7-97.6)	33.3 (21.6-47.1)	97.1 (95.4-98.2)	10.1 (6.1-16.7)	0.6 (0.5-0.8)	**0.66 (0.50-0.82)**
Surgery	31.0	71.4 (57.7-82.6)	96.3 (94.1-97.9)	37.0 (23.2-53.0)	99.1 (97.7-99.7)	19.2 (12.1-30.4)	0.3 (0.2-0.5)	**0.61 (0.56-0.66)**
PICU	0.6	33.3 (0.8-90.6)	94.4 (91.8-96.4)	3.7 (0.1-19.0)	99.5 (98.1-99.9)	5.9 (1.1-31.9)	0.7 (0.2-2.6)	**0.83***
CPR	0.2	100.0 (2.5-100)	94.5 (92.0-96.4)	100.0 (2.5-100)	100.0 (98.9-100)	18.0 (9.1-35.6)	0.0*	**0.95***
Sequelae	3.0	71.4 (35.9-91.8)	96.3 (94.1-97.9)	37.0 (17.3-61.4)	99.1 (97.7-99.7)	19.2 (10.8-34.0)	0.3 (0.1-0.8)	**0.93 (0.86-1.00)**

** 95% CI not calculated due to infrequent events*

Specifically, the PTI demonstrated good discriminative ability for clinical severity (AUROC: 0.97) and the presence of sequelae (AUROC: 0.93) (Supplementary Material). For both outcomes, NPV and specificity values were high, suggesting its use for identifying patients at low risk of these adverse events.

An exploratory analysis was conducted using a more stringent cutoff (PTI ≤ 6), originally proposed by Tepas et al., and showed an overall improvement in diagnostic per-

formance. Evaluation of the contingency tables and analysis of the AUROC curves demonstrated that using a more stringent criterion (PTI ≤ 6) improves the score's ability to rule out adverse outcomes in pediatric blunt trauma: high severity (LR+ 37.1 vs. 24.5) and sequelae (LR+ 36.6 vs. 19.2) [Supplementary material].

Finally, the reliability analysis showed a Kappa coefficient of 0.79 (95% CI 0.74–0.84, for PTI ≤ 8) for intraobserver agreement and 0.59 (95% CI 0.57–0.61, for PTI ≤ 8) for interobserver agreement, indicating good reproducibility of the scale.

DISCUSSION

The main finding of this study is that the PTI can function as a valid and reliable triage tool in a low-energy pediatric trauma setting. In this regard, its contribution is reflected in the contextualization of its utility at the national level. By comparing our findings—predominance of blunt trauma in children < 12 years old with no mortality—with those of a previous study in Cali, which reported a high prevalence of penetrating trauma and mortality among adolescents, this study demonstrates the versatility of the PTI: in our setting, it is a robust tool for ruling out adverse outcomes (*rule-out*), supported by NPV values close to 100% and high sensitivity, while in high-energy settings it is a powerful predictor of mortality.

Our findings on PTI performance are consistent with the international literature (Table 1), where its main strength over time has been its operational simplicity (< 2 minutes for triage, no laboratory testing) compared with complex scales such as PRISM III/TRISS[7,15]. Differences in performance, particularly in sensitivity and PPV, may be attributed to variations in the populations studied, as well as in the prevalence of severe trauma and the predominant mechanisms of injury.

This contextual divergence is key to interpreting the utility of the PTI. In Cali's high-energy trauma and violence setting, the PTI proved to be an exceptional predictor of mortality (AUROC: 0.93). In our low-energy trauma setting, the PTI stands out as an excellent tool for ruling out the need for complex interventions and the presence of sequelae (NPV: > 97%). Thus, the PTI demonstrates remarkable versatility, adapting as a robust predictor of different critical outcomes according to the epidemiological profile of trauma in the population served, thereby expanding its current utility.

The main strengths of this study include its prospective design, which minimizes information bias, and the formal analysis of intra- and interobserver reliability, which confirms the reproducibility of the scale. In addition, the focus on a specific pediatric population (< 12 years) provides valuable data for an age group with well-defined anatomical and physiological characteristics.

The main limitation was the small sample size (n = 470 vs. 696 calculated) resulting from the end of the prospective study period, which led to insufficient power to detect rare events: PICU admission, CPR, and mortality. This limitation accurately reflects the local epidemiology of low-energy blunt trauma due to falls (71%), in which these outcomes are uncommon. However, the diagnostic metrics of the PTI were favorable for important outcomes such as prolonged hospital stay, high severity, surgery, and sequelae [Table 3], with an NPV (> 97%), a high LR+ (> 10), and adequate PTI reliability (intraobserver Kappa 0.79, interobserver 0.59), validating its clinical utility for ruling out high severity and sequelae through AUROC analysis. The single-center design limits generalizability, although the results are consistent with the international literature on pediatric blunt trauma.

The excellent NPV of the PTI should be interpreted in light of the low prevalence of severe events in our cohort. As is well known, NPV increases mathematically in populations with low prevalence. This limitation applies to diagnostic validation studies in low-energy blunt trauma settings such as ours, but it precisely underscores the value of the PTI as a rule-out tool in similar epidemiological settings, as mentioned earlier.

Finally, our exploratory analyses suggest better performance of a PTI ≤ 6 (LR+ > 30 for severity, hospitalization, surgery, and sequelae) compared with a PTI ≤ 8 in low-energy blunt trauma. This is advantageous because increasing the LR+ could facilitate timely discharge, reducing false positives and the consequent burden on hospital resources. However, these findings require confirmation through formal comparative analyses and prospective external validation. In settings involving high-energy trauma / penetrating trauma, De los Ríos-Pérez et al.[13] suggested using a cutoff of ≤ 4. Historically, Ramenofsky et al. changed the PTI cutoff from ≤ 6 to ≤ 8 based on the threshold that best discriminated changes in mortality[10]. Accordingly, we recommend adapting the PTI cutoff to the epidemiological profile of trauma in each region.

CONCLUSIONS

The Pediatric Trauma Index is a useful, objective, and reproducible triage tool for the initial assessment of trauma in children under 12 years of age in the Colombian context. Its main clinical value lies in its ability to rule out adverse outcomes, such as clinical severity and the presence of sequelae, using a cutoff of PTI > 8, given its high negative predictive value. Exploratory analyses suggest that a cutoff of PTI ≤ 6 may be beneficial, but this requires validation in larger independent cohorts.

Funding

No funding was received for the research, authorship, and/or publication of this article.

Conflicts of interest

I declare that there are no commercial or financial conflicts of interest in this research.

Author contributions

Víctor Manuel Mora-Bautista: Conceptualization, Writing – original draft, Writing – review and editing, Investigation, Validation, Formal analysis; Andrea Milena

González-Gómez: Conceptualization, Writing – review and editing, Validation, Project administration, Supervision, Investigation, Resources, Formal analysis, Funding acquisition, Writing – original draft, Data curation, Methodology, Visualization; German Lauro Pradilla-Arenas: Conceptualization, Validation, Methodology, Formal analysis, Writing – original draft, Investigation, Writing – review and editing, Supervision, Visualization; Nicolás Efrén Espinosa Ardila: Investigation, Supervision, Methodology, Data curation; David Andrés Sánchez Hernández: Methodology, Investigation, Supervision, Data curation; Ricardo Galindo Rodríguez: Data curation, Investigation, Supervision, Methodology

Use of AI

Syntax and spelling review (Perplexity Pro AI)

Data availability

The data supporting the findings of this study are available upon request from the corresponding author.

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