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PREDICCIÓN DE SUPERVIVENCIA EN TRAUMA PEDIÁTRICO: EVALUACIÓN DE ESCALAS PRONÓSTICAS Y DESARROLLO DE NUEVOS MODELOS EN UN CENTRO DE TRAUMA EN COLOMBIA

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Programa de Doctorado en Metodología de la Investigación Biomédica y Salud Pública

TESIS DOCTORAL

“PREDICCIÓN DE SUPERVIVENCIA EN TRAUMA PEDIÁTRICO: EVALUACIÓN DE ESCALAS PRONÓSTICAS Y DESARROLLO DE NUEVOS MODELOS EN UN CENTRO DE TRAUMA EN COLOMBIA”

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Dibujo hecho por Martin Franco De los Rios, de Cali Colombia (hijo de la Doctoranda). Ilustra su visión de la ciudad y la interacción de los niños en ella.

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PRESENTACION

Soy médica y cirujana, egresada de la Universidad del Valle (Cali, Colombia) en el año 2003. Me formé como especialista en Pediatría y sus áreas específicas en España, culminando mi especialización en el año 2011.

Desde hace más de una década, desarrollo mi actividad asistencial en el servicio de urgencias pediátricas del Hospital Universitario Fundación Valle del Lili, institución en la cual también hago parte activa de la investigación con el equipo del Centro de Investigaciones Clínicas. Mi ejercicio profesional —asistencial, docente e investigador— se ha centrado especialmente en la atención de urgencias pediátricas, con especial interés en el trauma pediátrico en un contexto de alta complejidad.

En el ámbito académico, formo parte del cuerpo docente del programa de Medicina de la Universidad Icesi (Cali, Colombia), con énfasis en la utilización de la simulación clínica como estrategia pedagógica clave para el desarrollo y fortalecimiento de competencias clínicas en escenarios seguros y controlados.

Esta tesis doctoral representa la convergencia de mis intereses profesionales y académicos, orientados de forma consistente hacia el cuidado integral de la infancia, el compromiso con la docencia médica y la generación de conocimiento útil, contextualizado y aplicable en entornos clínicos de alta complejidad y en regiones con desafíos estructurales en salud pública.

CONFLICTOS DE INTERES

La doctoranda declara que no existe ningún conflicto de interés que haya influido en el desarrollo, análisis, interpretación o presentación de los resultados de esta tesis doctoral.

AGRADECIMIENTOS

Este trabajo representa el cierre de un ciclo profundamente significativo en mi vida personal y profesional, y no habría sido posible sin el apoyo constante y generoso de muchas personas a lo largo de este camino.

Quiero expresar mi agradecimiento con la Universitat Autònoma de Barcelona, institución que ha acompañado y respaldado mi proceso académico, haciendo posible la realización de este doctorado. Extiendo este reconocimiento al Departamento de Pediatría, a María José Díaz y a todo el personal administrativo, por su amabilidad, diligencia y gestión eficiente a lo largo de estos años, superando las barreras físicas de la distancia. Mi gratitud también con las Comisiones de Seguimiento, cuyas orientaciones y observaciones constructivas fueron esenciales para mantener el rumbo y la calidad del proyecto en cada una de sus etapas.

De manera muy especial, quiero manifestar mi agradecimiento sincero con el Dr. Xavier Bonfill Cosp, tutor de mi tesis, por su guía experta, acompañamiento cercano y compromiso permanente durante todo el proceso. Su apoyo ha sido invaluable y un pilar fundamental para el desarrollo y culminación de esta tesis, sin él, no habría sido posible. Su apoyo fue clave para avanzar en cada etapa del doctorado.

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La experiencia y dedicación de ambos, el Dr. Fandiño y el Dr. García, fueron esenciales para la consolidación de este proyecto. Me impulsaron a alcanzar niveles de exigencia inimaginables por mí misma. Su confianza en mi trabajo, su liderazgo inspirador y su ejemplo han dejado una huella profunda en mi formación y seguirán guiando mi camino profesional.

Reconozco con especial gratitud al Hospital Universitario Fundación Valle del Lili, a la Universidad Icesi y al Centro de Investigaciones Clínicas por brindarme el entorno académico y clínico propicio para el desarrollo de esta investigación. A mis colegas y estudiantes, por los diálogos, preguntas e ideas que enriquecieron mi pensamiento crítico y reforzaron mi compromiso con la formación médica y con la excelencia científica.

A la Dra. Diana Caicedo Borrero, cuya orientación académica y metodológica fue de gran valor para el desarrollo de este trabajo, aportando claridad, profundidad y precisión. Sus aportes enriquecieron el enfoque, fortalecieron el rigor y contribuyeron a la solidez científica de esta tesis.

Agradezco de manera profunda a mi familia, cuyo amor incondicional, paciencia y respaldo han sido cruciales en cada etapa de esta travesía. A mi esposo, por su confianza absoluta en mí, por transmitirme siempre — en cada palabra — su firme convicción de que lograría mi gran sueño de culminar la tesis doctoral; por motivarme en momentos de cansancio, incertidumbre, desesperanza y a veces desesperación; y por recordarme, cada día, el sentido más profundo de este gran esfuerzo. A Martín, mi hijo, por comprender amorosamente el tiempo dedicado al estudio, aun implicando renunciar a compartir muchos momentos juntos. A mi maravillosa madre, por su apoyo silencioso, su fe inquebrantable, sus palabras siempre optimistas y alentadoras. A mi padre — que ya no está físicamente, pero que vive en lo más profundo de mi corazón — y a mi madre, a ambos, por enseñarme desde siempre el valor del esfuerzo y la educación. A toda mi familia, gracias por su comprensión durante mis ausencias y por acompañarme con generosidad a lo largo de este recorrido. Ha sido un proceso extenso, marcado por múltiples desafíos, migraciones, un enorme costo afectivo y un esfuerzo inmenso por dar lo mejor de mí como persona, estudiante y profesional.

A todos los niños y adolescentes que han sido pacientes del hospital, y a sus familias, por su valiosa contribución. A través de sus datos, hoy podemos fundamentar nuevas rutas para mejorar la atención en salud en nuestro país. Aun sin saberlo, representan la motivación última de esta investigación: contribuir a una atención más humana, eficiente y contextualizada.

Este trabajo nació y se desarrolló en medio de una realidad trágica y dolorosa que vive mi país, Colombia, y particularmente mi región, donde la violencia sigue cobrando de forma alarmante la vida de niños y adolescentes. Cada caso registrado en este estudio representa una historia de vida interrumpida. Agradezco profundamente haber podido estar en mi país para llevar a cabo esta investigación, que ha significado un desafío y un acto de compromiso. Ha sido una experiencia inmensamente significativa, conmovedora y una oportunidad invaluable para aportar,

desde la ciencia y el rigor académico, a la construcción de conocimiento que contribuya a transformar una realidad que no podemos ni debemos ignorar.

A todas las personas que, de una u otra forma, han creído en mí: gracias, de corazón.

“El dolor por la muerte de un niño es inconmensurable, más aún cuando se presenta súbitamente, a consecuencia de una lesión”

— Organización Mundial de la Salud, 2008

INDICE

LISTA DE ABREVIATURAS

ACS COT	American College of Surgeons Committee on Trauma
AIC	Akaike Information Criterion
AIS	Abbreviated Injury Scale
ATLS	Advanced Trauma Life Support
AUROC	Area Under the Receiver Operating Characteristic curve
BIC	Bayesian information criterion
CDC	Centers for Disease Control and Prevention
CI	Confidence interval
CITL	Calibration-In-The-Large
DEF	DEFinitive outcome-based evaluation
DSP	Diagnosis-specific survival probability
ECG	Escala Coma de Glasgow
E:O	Observed: Expected ratio
HL	Hosmer-Lemeshow
ICD-10	International classification of diseases, 10th edition
ICISS	International Classification of Diseases-based Injury Severity Score
ICU	Intensive Care Unit
IQR	Interquartile range
ISS	Injury Severity Score
LMIC	Low- and Middle-Income Countries
MTOS	Major Trauma Outcome Study
NICE	National institute for health and care excellence
OR	Odds ratio
PAHO	Pan American Health Organization

Peds-TRISS	Age-adjusted trauma injury severity score
PTS	Pediatric Trauma Score
RIPS	Registros Individuales de Prestación de Servicios de Salud
RTS	Revised Trauma Score
SGSSS	Sistema General de Seguridad Social en Salud
TARN	Trauma Audit and Research Network
TRIPOD	Transparent Reporting of a multivariable prediction model for Individual Prognosis Or Diagnosis
TRISS	Trauma Injury Severity score
UNICEF	United Nations Children's Fund
WHO	World Health Organization

RESUMEN

Antecedentes: Aunque los indicadores globales de salud han mejorado, esta evolución ha sido desigual entre las diferentes regiones del mundo. En particular, la mortalidad por trauma en América Latina no ha experimentado avances en las últimas décadas, posicionando al trauma como un grave problema de salud pública con una alta carga de morbimortalidad. A pesar de los beneficios demostrados con el uso de escalas de severidad en el pronóstico clínico, su uso en la región es limitado y, hasta la fecha de realización de esta tesis, no se han reportado estudios que evalúen su desempeño en la población pediátrica colombiana. Esta tesis se propuso describir la casuística local y evaluar el desempeño de algunas escalas en la predicción de supervivencia frente al trauma.

Métodos: Esta tesis se presenta como un compendio de tres artículos publicados en revistas indexadas, revisadas por pares y clasificadas en cuartiles Q1 y Q2. Se realizó una cohorte retrospectiva en niños menores de 18 años atendidos por lesiones en un centro de trauma de alta complejidad en Cali, Colombia. Se hizo un análisis descriptivo de las características clínicas y demográficas de los pacientes, la naturaleza de las lesiones y los desenlaces, así como de las puntuaciones obtenidas en diferentes escalas. Se evaluó el desempeño de tres escalas pronósticas: Pediatric Trauma Score (PTS), International Classification of Diseases 10th Revision-based Injury Severity Score (ICISS) y Trauma and Injury Severity Score (TRISS). Su capacidad predictiva de supervivencia fue evaluada mediante análisis de discriminación (área bajo la curva ROC -

AUROC) y calibración (prueba de Hosmer-Lemeshow). Además, se desarrollaron nuevos modelos predictivos a partir de ajustes en las variables originales de TRISS e ICISS, los cuales fueron comparados estadísticamente con sus versiones estándar y sometidos a validación interna mediante la técnica de bootstrapping. Cada artículo del compendio corresponde a la evaluación individual de cada una de las escalas.

Resultados: 1047 niños fueron incluidos en el estudio, con una edad mediana de 12 años, de los cuales el 73.7% fueron del sexo masculino. Las principales causas de lesión fueron los accidentes de tránsito (31.5%) y la violencia interpersonal (29%). La mortalidad fue del 5.9%, siendo el homicidio la principal causa de muerte. La evaluación del PTS mostró un desempeño excelente en todas las métricas analizadas. Las escalas TRISS e ICISS presentaron buena capacidad de discriminación, pero una calibración deficiente. Los modelos predictivos desarrollados a partir de estas escalas mejoraron significativamente la precisión pronóstica.

Conclusiones: La mayoría de las lesiones y muertes se produjo en adolescentes. La violencia interpersonal fue la causa más frecuente de muerte en este grupo de edad. El PTS se posiciona como una herramienta sólida, potente y fiable en la predicción de supervivencia en niños. Las escalas TRISS e ICISS mostraron limitaciones en su versión original, pero mejoraron su desempeño tras ajustes específicos en sus variables.

RESUM

Antecedents: Tot i que els indicadors globals de salut han millorat, aquesta evolució ha estat desigual entre les diferents regions del món. En particular, la mortalitat per traumatisme a l'Amèrica Llatina no ha experimentat avenços significatius durant les darreres dècades, fet que posiciona el trauma com un greu problema de salut pública amb una elevada càrrega de morbiditat i mortalitat. Malgrat els beneficis demostrats de l'ús d'escales de gravetat en el pronòstic clínic, el seu ús a la regió és limitat i, fins a la data de realització daquesta tesi, no s'han publicat estudis que n'avaluïn el rendiment en població pediàtrica colombiana. Aquesta tesi doctoral es va proposar descriure la casuística local i avaluar el rendiment d'algunes escales en la predicció de la supervivència davant del trauma.

Mètodes: Aquesta tesi es presenta com un compendi de tres articles publicats en revistes indexades, revisades per parells i classificades en els quartils Q1 i Q2. Es va dur a terme un estudi de cohort retrospectiu en nens menors de 18 anys atesos per lesions en un centre de trauma d'alta complexitat a Cali, Colòmbia. Es va fer una anàlisi descriptiva de les característiques clíniques i demogràfiques dels pacients, la naturalesa de les lesions i els desenllaços, així com de les puntuacions obtingudes en diverses escales. Es va avaluar el rendiment de tres escales pronòstiques: el Pediatric Trauma Score (PTS), l'International Classification of Diseases 10th Revision-based Injury Severity Score (ICISS) i el Trauma and Injury Severity Score (TRISS). La seva capacitat predictiva de supervivència es va valorar mitjançant l'anàlisi de discriminació (àrea sota la corba ROC – AUROC) i de

calibratge (prova de Hosmer-Lemeshow). A més, es van desenvolupar nous models predictius a partir d'ajustos en les variables originals del TRISS i l'ICISS, els quals es van comparar estadísticament amb les seves versions estàndard i es van validar internament mitjançant la tècnica de bootstrapping. Cada article del compendi correspon a l'avaluació individual de cadascuna de les escales.

Resultats: Es van incloure 1.047 nens a l'estudi, amb una edat mitjana de 12 anys, dels quals el 73,7% eren de sexe masculí. Les principals causes de lesió van ser els accidents de trànsit (31,5%) i la violència interpersonal (29%). La mortalitat global va ser del 5,9%, sent l'homicidi la causa més freqüent de mort. L'avaluació del PTS va mostrar un rendiment excel·lent en totes les mètriques analitzades. Les escales TRISS i ICISS van presentar bona capacitat discriminativa, però un calibratge deficient. Els models predictius desenvolupats a partir d'aquestes escales van millorar significativament la precisió pronòstica.

Conclusions: La majoria de lesions i defuncions es van produir en adolescents. La violència interpersonal va ser la causa més freqüent de mort en aquest grup d'edat. El PTS es posiciona com una eina sòlida, potent i fiable en la predicció de la supervivència infantil. Les escales TRISS i ICISS van mostrar limitacions en la seva versió original, però van millorar el seu rendiment després d'ajustos específics en les seves variables.

ABSTRACT

Background: Although global health indicators have improved, progress has been uneven across different regions of the world. In particular, trauma-related mortality in Latin America has shown little improvement in recent decades, positioning trauma as a major public health issue with a high burden of morbidity and mortality. Despite the demonstrated benefits with the use of severity scores in clinical prognosis, their use in the region remains limited and, to date of this thesis, no studies have been reported that evaluate their performance in the Colombian pediatric population. This doctoral thesis aimed to describe local caseload characteristics and assess the performance of selected severity scores in predicting trauma survival.

Methods: This thesis is presented as a compendium of three peer-reviewed articles published in Q1 and Q2 indexed journals. A retrospective cohort study was conducted in children under 18 years of age treated for injuries at a high-complexity trauma center in Cali, Colombia. A descriptive analysis was performed of patients' clinical and demographic characteristics, injury mechanisms, outcomes, and scores from various trauma severity scales. The performance of three prognostic scores was evaluated: the Pediatric Trauma Score (PTS), the International Classification of Diseases 10th Revision-based Injury Severity Score (ICISS), and the Trauma and Injury Severity Score (TRISS). Predictive performance was assessed using discrimination (area under the ROC curve – AUROC) and calibration (Hosmer–Lemeshow test). Additionally, new predictive models were developed by adjusting the original TRISS and ICISS variables. These models were statistically compared to their standard versions and internally validated using the bootstrapping technique. Each article in the compendium focused on the individual evaluation of one of the scores.

Results: A total of 1,047 children were included in the study, with a median age of 12 years; 73.7% were male. The leading causes of injury were road traffic accidents (31.5%) and interpersonal violence (29%). Overall mortality was 5.9%, with homicide being the most common cause of death. The PTS demonstrated excellent performance across all evaluated metrics. TRISS and ICISS showed good discrimination but poor calibration. Predictive accuracy improved significantly in the newly developed models based on these scores.

Conclusions: Most injuries and deaths occurred in adolescents. Interpersonal violence was the leading cause of death in this age group. The PTS emerged as a robust, reliable tool for survival prediction in pediatric trauma. Although the original versions of TRISS and ICISS had limitations, their predictive performance improved following specific variable adjustments.

1. INTRODUCCION

1.1 Contexto epidemiológico:

Las lesiones como problema de salud

Las lesiones de causa externa — incluídas aquellas originadas por accidentes de tránsito, violencia interpersonal, lesiones autoinfligidas y caídas, entre otras — constituyen una de las principales causas de muerte y discapacidad en todo el mundo (1). Se estima que son responsables del 8% de todas las muertes y del 8% de los años vividos con discapacidad a nivel global (2), constituyéndose en un grave problema de Salud Pública mundial. La población joven es la mayoritariamente afectada, pues entre los 5 y 29 años, las lesiones ocupan los primeros lugares como causa de muerte (3,4). Esto supone una importante carga en los sistemas sanitarios y financieros de cada país considerando que más allá de las 4.4 millones de muertes anuales a causa de una lesión (5), son decenas de millones más los que sufren lesiones no fatales pero que requieren atención médica y rehabilitación a largo plazo (2), sin desestimar el costo económico directo e indirecto derivado de los años perdidos debido a muerte prematura (6) o discapacidad (5,7).

De acuerdo con el estudio Global Burden Disease, la salud global y la expectativa de vida han mejorado en las últimas décadas (8); no obstante, y según datos del mismo estudio, entre los 5 y 14 años, las lesiones continúan siendo la primera causa de muerte en el mundo desde hace más de 30 años (9). Causan más años de vida perdidos antes de los 18 años que la muerte súbita infantil, el cáncer y las enfermedades infecciosas juntas (10). Es tal la magnitud de las lesiones que se les ha llegado a considerar “el asesino número 1 de los jóvenes”, por instituciones reconocidas como la Organización Mundial de la Salud (OMS) (11) y el Centers for Disease Control and Prevention (CDC) (12).

En el contexto regional de América Latina, las lesiones intencionales ocupan un lugar importante como causa de muerte, siendo la segunda causa a partir de los 15 años (9). La tasa de mortalidad por homicidio es de 19,2 por cada 100.000 habitantes, representando más del triple del promedio mundial (6,2 por 100.000 habitantes) (1). Esta elevada mortalidad se ha mantenido consistentemente alta en la región durante más de dos décadas (13), y datos recientes alertan sobre un incremento entre los adolescentes (1,14).

Dentro de la región, Colombia presenta tasas de homicidio que superan el promedio latinoamericano, y en Cali —un importante centro urbano del país— la situación es crítica pues supera ampliamente el promedio mundial (1,15). Con 66,8 homicidios por cada 100.000 habitantes (15), sobrepasa en más de diez veces la tasa global, constituyéndose en una de las ciudades más violentas del mundo (16).

Este contexto nos lleva a considerar las lesiones como un importante problema de Salud Pública mundial, cuya magnitud y características difieren entre las diferentes regiones, siendo el trauma intencional por violencia interpersonal, es decir por homicidio, de especial relevancia en América Latina y en Cali, Colombia, la ciudad donde fue desarrollado el estudio.

Intencionales o no, se trata de muertes prevenibles y hacia allí deberían ir encaminados nuestros esfuerzos y dirigidas nuestras intervenciones para evitar que ocurran las lesiones. Sin embargo, las lesiones siguen ocurriendo, y debemos estar preparados para su atención óptima y oportuna, pues una vez se presenta una lesión grave, la muerte ocurre en minutos (17). En este sentido, para optimizar la atención de estos pacientes se han propuesto diferentes estrategias, entre éstas, una con valor demostrado es la implementación de herramientas de predicción de supervivencia (18) como las escalas de trauma (19), útiles en el triage y direccionamiento de pacientes, predicción de supervivencia y como elemento de medición de calidad de atención de centros de trauma, entre otras aplicaciones clínicas relevantes (20-23). Las escalas de trauma se han utilizado en pediatría desde los 80's y son ampliamente recomendadas por autoridades internacionales, como el American College of Surgeons Committee on Trauma (ACS COT) y por el National Institute for Health and Care Excellence (NICE) del Reino Unido (24,25). Estas organizaciones reconocen la utilidad de su aplicación para el funcionamiento eficaz de los sistemas de atención de trauma.

Se evaluó el desempeño de tres escalas, lo cual representa el eje principal de esta tesis, de donde se desprenden los tres artículos que la conforman: Primero, la escala Pediatric Trauma Score (PTS), por haberse diseñado específicamente para ser aplicada en niños (26) y ser recomendada por el American College of Surgeons Committee on Trauma en su manual Advanced Trauma Life Support (17), referente internacional para el manejo del paciente politraumatizado.

En segundo lugar, se evaluó la International Classification of Diseases-based Injury Severity Score (ICISS), seleccionada por su facilidad de cálculo a partir de los diagnósticos codificados en la CIE-10 (27), registrados sistemáticamente en bases de datos administrativas, de obligatorio registro en el sistema de salud colombiano, lo que permite su uso sin requerimiento de recursos adicionales.

En tercer lugar, se evaluó la escala TRISS, por ser una de las escalas más utilizadas en investigación de predicción de supervivencia en trauma y en evaluación de calidad de atención de centros de trauma.

Como paso adicional, y siguiendo las recomendaciones de la evidencia disponible que sugiere combinar datos anatómicos y fisiológicos, e incluir variables demográficas cuantitativas para mejorar la calidad de la investigación y el desempeño de modelos predictivos de mortalidad en trauma (18), desarrollamos nuevos modelos predictivos basados en las escalas ICISS y TRISS. En el caso de ICISS, y considerando la alta prevalencia del trauma craneoencefálico como principal causa de muerte en niños (28) y la importancia de la respuesta fisiológica al trauma en este grupo de edad (29), se construyó un nuevo modelo predictivo combinado que además de ICISS, incorpora la variable Escala de Coma de Glasgow (ECG) y comparamos el desempeño de ambos modelos en la población de nuestro estudio. En cuanto a la TRISS, dado que excluye la edad cuando se aplica en niños, y por tanto con resultados de desempeño variables en la literatura (30,31), desarrollamos un nuevo modelo predictivo que incluye la edad, mediante el recalculo de los coeficientes, dando lugar al modelo denominado Peds-TRISS.

Finalmente, con el objetivo de aportar también al análisis de la calidad de la atención en trauma pediátrico, se utilizó la escala TRISS en nuestra cohorte para la evaluación comparativa de resultados. Esta decisión se basó en la utilidad previamente demostrada de dicha escala en estudios internacionales como indicador de desempeño hospitalario y herramienta de benchmarking, permitiendo identificar posibles áreas de mejora en la atención brindada a pacientes lesionados (32).

Cabe resaltar que las tres escalas, fueron diseñadas en países (Estados Unidos y Canadá) con condiciones sociales, sistemas de salud y características epidemiológicas distintas a las de nuestra región. Dichos países cuentan con una infraestructura vial organizada y con sistemas de atención médica y traumatológica más estructurados y especializados. Asimismo, los mecanismos de trauma en dicho contexto también difieren de los observados en nuestra región. Además, estas escalas fueron diseñadas hace varias décadas, periodo en el que se han producido importantes avances tecnológicos y se han desarrollado protocolos específicos para la atención del paciente traumatizado.

Por lo tanto, nos propusimos evaluar el desempeño de estas escalas en términos de capacidad de predicción de supervivencia, en una población pediátrica de un país latinoamericano, contexto poco explorado hasta la fecha en la literatura internacional. A continuación, describimos las tres escalas evaluadas en este trabajo de tesis.

1.2 Escalas de clasificación de severidad del trauma

Pediatric Trauma Score (PTS)

Fue descrita en 1987 por Tepas et al (26) Su aplicación en niños combina variables fisiológicas y anatómicas (peso, estado de vía aérea, presión arterial sistólica, estado del sistema nervioso central, fracturas y heridas) para clasificar la gravedad de la lesión. Proporciona una puntuación entre -6 y +12, donde las puntuaciones más bajas indican mayor gravedad. Una puntuación ≤8 sugiere que el paciente debe ser trasladado a un centro de traumatología debido a un riesgo significativamente mayor de mortalidad (33).

International Classification of Diseases, 10th Revision (ICD-10)-based Injury Severity Score (ICISS)

Evalúa el componente anatómico de las lesiones. Primero, se calcula la Probabilidad de Supervivencia específica del Diagnóstico (Diagnosis-specific Survival Probability (DSPs) de cada lesión codificada en la CIE-10, y luego se calcula la ICISS, que es la probabilidad de supervivencia de cada paciente basada en el producto de sus DSPs (anteriormente denominada razón de riesgo de supervivencia) (27,34). Su fórmula es:

$$DSPs = \frac{\text{Número de sobrevivientes con un diagnóstico CIE-10}}{\text{Número de pacientes con un diagnóstico CIE-10}}$$

$$ICISS = DSPs_{inj1} \times DSPs_{inj2} \times \ldots DSPs_{inj\ last}$$

Donde $DSPs_{inj1}$, $DSPs_{inj2}$ y $DSPs_{inj\ last}$ representan la probabilidad de supervivencia de la lesión 1, la lesión 2 y la última lesión, respectivamente, el resultado varía de 0 a 1.

Trauma and Injury Severity Score (TRISS)

Es una escala que combina variables fisiológicas y anatómicas y se utiliza para estimar la probabilidad de supervivencia del paciente tras un traumatismo. Para su cálculo, se utilizan: el mecanismo de la lesión (cerrado o penetrante), dos escalas (Revised Trauma Score-RTS e Injury Severity Score-ISS), y la edad. La fórmula es la siguiente:

$$Ps = \frac{1}{1 + e^{-b}}$$

Donde: Ps = probabilidad de supervivencia, ***e*** es una constante (2,718282, base del logaritmo natural o neperiano), b = b_0 + (b_1xRTS) + (b_2xISS) + ($b_3$xedad). Aquí, b_0, b_1, b_2 y b_3 son coeficientes que difieren según el mecanismo de la lesión y se derivan de un modelo de regresión logística basado en datos del Major Trauma Outcome Study (MTOS) de Norteamérica. La variable edad es dicotómica, adquiriendo un valor de 1 en los mayores de 54 años y un valor de 0 en los que tienen 54 años o menos, anulándose por tanto de la ecuación en niños (35,36).

Escalas necesarias para el cálculo de TRISS

Revised Trauma Score (RTS)

En uso desde 1989, la RTS considera tres variables fisiológicas en su fórmula: ECG, presión arterial y frecuencia respiratoria. Los valores de cada variable se agrupan en rangos, se codifican, se multiplican por coeficientes derivados del MTOS mediante un modelo de regresión logística y se suman para obtener un valor final entre 0 y 7.84, donde los valores más bajos indican mayor gravedad (37).

Abbreviated Injury Scale (AIS) and Injury Severity Score (ISS)

La AIS sirve como base para calcular la ISS. La AIS clasifica individualmente cada lesión, considerando seis regiones corporales, y asigna un valor según la ubicación, el tipo y la gravedad en una escala ordinal del 1 al 6. Una puntuación de 3 indica una lesión grave, mientras que 6 representa la lesión más crítica, incompatible con la posibilidad de sobrevivir (38). Se han desarrollado diversas versiones desde 1971, y para nuestro estudio, utilizamos la versión de 2015, que incorpora mejoras y ventajas como herramienta de investigación (39). La ISS consiste en sumar los cuadrados de los tres segmentos anatómicos con peor AIS (lesiones más graves) lo que resulta en un valor entre 1 y 75. Una persona con una puntuación de 16 o superior se considera gravemente lesionada (40). Un AIS de 6 en cualquier lesión confiere automáticamente un ISS de 75, con una supervivencia incierta (22,41).

Tanto el AIS como el ISS han sido ampliamente reconocidos y aceptados internacionalmente durante décadas por la comunidad científica y sanitaria, lo que confiere varias ventajas como la estandarización del lenguaje hablado entre los diferentes actores involucrados en la atención y evaluación del trauma a la vez que facilita la comparación de pacientes y sus desenlaces entre centros.

1.3 Evaluación comparativa de resultados

Otra de las estrategias para reducir la carga de morbimortalidad por lesiones es la realización sistemática de actividades que mejoren la calidad de atención de los centros de trauma, como la evaluación comparativa de las tasas de mortalidad o supervivencia en el propio centro con referentes nacionales o internacionales. Esta práctica, respaldada por organismos como la OMS en sus Guidelines for Trauma Quality Improvement Programmes (42) y por el Colegio Americano de

Cirujanos en Resources for Optimal Care of the Injured Patient (32) permite identificar deficiencias en el proceso de atención para promover intervenciones dirigidas al mejoramiento continuo de la calidad de asistencial (42-44).

1.4 La investigación como estrategia

Pese a la situación alarmante de las lesiones en el mundo, la investigación en trauma es deficiente en comparación con otras áreas de la medicina, y el panorama es aún peor en el caso de trauma pediátrico y preocupante si nos delimitamos a población pediátrica latinoamericana donde la investigación disponible es precaria. No solo en términos de evidencia científica generada, sino que la inversión económica asignada a esta área no es proporcional a la carga de morbilidad y mortalidad ocasionada (45-49). Esto limita la disponibilidad de datos que permitan proponer estrategias de intervención que mitiguen la incidencia del trauma y sus devastadoras consecuencias.

1.5 Justificación de la Tesis

La alta carga de morbimortalidad asociada al trauma en niños y adolescentes, especialmente en contextos de elevada violencia como América Latina — y en particular Colombia —, plantea la necesidad imperiosa de fortalecer las estrategias de intervención orientadas a mejorar los desenlaces clínicos en esta población. En Colombia, los indicadores de violencia superan tanto los promedios regionales como los mundiales, lo que subraya la urgencia de generar evidencia contextualizada que contribuya a optimizar la atención en salud.

Si bien la literatura internacional ha demostrado la efectividad de diversas intervenciones para mejorar el pronóstico en pacientes traumatizados, la evidencia proveniente de nuestra región continúa siendo limitada, especialmente en el ámbito del trauma pediátrico. Esta limitación se manifiesta no solo en la escasez de estudios descriptivos, sino también en la ausencia de validaciones locales de escalas de clasificación desarrolladas en otros contextos geográficos, pese a su utilidad reconocida para la estimación pronóstica, la gestión eficiente de recursos y la mejora de la calidad asistencial.

Antes del desarrollo de esta tesis, no se identificaron estudios publicados que evaluaran el desempeño de escalas validadas en población pediátrica colombiana lo cual reviste particular importancia dado que el país presenta características epidemiológicas y sistemas de atención que difieren sustancialmente de los contextos en los que estas escalas fueron originalmente desarrolladas y validadas.

En respuesta a esta brecha, nos propusimos describir las características clínicas y lesionales de los niños atendidos en un centro de trauma de alta complejidad en la región, evaluar el rendimiento de distintas escalas en la predicción de supervivencia, y desarrollar nuevos modelos predictivos que mejoren la precisión pronóstica en este grupo etario.

En este sentido, la presente investigación aborda un problema prioritario de salud pública en la región, evalúa el desempeño de escalas internacionalmente reconocidas en un contexto geográfico y poblacional distinto, y propone herramientas predictivas adaptadas al entorno local colombiano y latinoamericano. Con ello, no solo se contribuye al cierre de una brecha significativa en el conocimiento, sino que también se ofrecen estrategias aplicables que pueden orientar la toma de decisiones clínicas y mejorar la calidad de la atención brindada a los niños que sufren lesiones.

2. OBJETIVOS

2.1 Objetivo general

Como objetivo general nos planteamos determinar las características, magnitud y severidad de las lesiones sufridas por una cohorte retrospectiva de niños ingresados en el Hospital Universitario Fundación Valle del Lili, en Cali, Colombia, y evaluar el desempeño de diferentes escalas en la predicción de supervivencia de esta población pediátrica.

2.2 Objetivos específicos

- Describir las características demográficas y clínicas de los pacientes menores de 18 años admitidos entre 2011 y 2019 en el Servicio de Urgencias del Hospital Universitario Fundación Valle del Lili, en Cali, Colombia.

- Analizar la frecuencia, tipo y gravedad de las lesiones presentadas por los pacientes incluidos en la cohorte.

- Evaluar el desempeño de las escalas PTS, ICISS y TRISS en la predicción de supervivencia en la población estudiada.

- Desarrollar nuevos modelos predictivos que mejoren la capacidad pronóstica de escalas existentes al ser aplicadas en pacientes pediátricos.

3. METODOLOGIA

La presente Tesis se desarrolló bajo la modalidad de compendio de publicaciones. Esta sección describe de manera integrada los aspectos metodológicos comunes a los tres estudios que conforman el compendio, incluyendo el diseño del estudio, los criterios de inclusión y exclusión, las fuentes de información, las variables analizadas y los procedimientos estadísticos aplicados. La metodología específica de cada artículo se detalla en sus respectivas secciones, mientras que este apartado proporciona una visión general del enfoque metodológico adoptado para responder a los objetivos de la investigación.

3.1 Metodología general de los estudios

Diseño y lugar del estudio

Se realizó un estudio observacional de una cohorte retrospectiva de niños admitidos entre enero de 2011 y mayo de 2019 en el Servicio de Urgencias del Hospital Universitario Fundación Valle del Lili, en Cali, Colombia. El hospital es una institución que atiende patologías de alto nivel de complejidad incluyendo trauma severo, siendo uno de los grandes centros de trauma del país, referente en el suroccidente colombiano, si bien atiende todos los niveles de complejidad. El hospital cuenta con 721 camas de hospitalización, 250 de ellas en cuidado crítico, 40 en cuidado critico pediátrico y 10 en cuidado critico de trauma. Atiende alrededor de 8000 casos de trauma anualmente, de los cuales aproximadamente 1000 son severamente lesionados y 700 requieren activación de código de trauma, es decir, el equipo de mayor nivel de activación. Colombia es un país latinoamericano al noroeste de Suramérica, con 52.695.952 (50) habitantes, clasificado según el Banco Mundial, como un país de ingresos medios-altos (51) y Cali, la tercera ciudad del país en términos demográficos y económicos, con 2.283.846 habitantes (52).

Participantes

Se incluyeron los pacientes menores de 18 años quienes recibieron atención en el servicio de Urgencias del Hospital Universitario Fundación Valle del Lili por lesiones de causa externa derivadas de un traumatismo, con códigos diagnósticos al egreso entre S00 y T149 de la Clasificación Internacional de Enfermedades, décima revisión, CIE-10 (53), que requirieron hospitalización o una estancia hospitalaria mayor a 6 horas o que fallecieron desde su ingreso a urgencias.

Se excluyeron los pacientes con lesiones relacionadas con quemaduras, ahogamientos, cuerpos extraños o intoxicaciones. También se excluyeron los pacientes con patologías crónicas oncológicas, hematológicas, metabólicas u osteoarticulares que pudieran condicionar el abordaje o desenlace del paciente. Otras exclusiones fueron los pacientes procedentes de otras regiones (fuera del Cauca o Valle del Cauca) o con un tiempo transcurrido mayor a 24 horas entre el trauma y el ingreso al hospital. También se excluyeron los pacientes remitidos de otros hospitales que hubieran sido intervenidos quirúrgicamente, pues esto impedía la clasificación de sus lesiones iniciales y su severidad y por tanto conllevaba a una clasificación errónea de los pacientes. Además, los pacientes remitidos a otro hospital antes del día 30 de hospitalización fueron también excluidos debido a la imposibilidad de verificar su estado vital (vivo o muerto) en ese momento, aunque la probabilidad de este desenlace era muy baja porque esta remisión ocurría desde el mayor nivel de complejidad de la atención.

Fuentes de datos y medición

Registro Individual de Prestación de Servicios de Salud (RIPS)

La selección de pacientes se realizó a partir del Registro Individual de Prestación de Servicios de Salud (RIPS), un sistema nacional obligatorio del Sistema General de Seguridad Social en Salud (SGSSS) de Colombia, que documenta todos los servicios de salud brindados. Este registro recopila información sociodemográfica, diagnósticos codificados en CIE-10, procedimientos realizados, tipo de atención recibida, destino al alta, estado vital y causa de muerte, cuando aplica (54). A partir del RIPS se aplicaron los criterios de inclusión del estudio y se obtuvieron las variables sociodemográficas.

Revisión de historias clínicas electrónicas

Una vez identificados los pacientes mediante el RIPS, se llevó a cabo una revisión exhaustiva de los expedientes clínicos electrónicos para completar la recolección de variables clínicas y las relacionadas con el trauma. El proceso de revisión combinó la extracción sistemática de datos estructurados con la revisión manual de información no estructurada. Esta revisión permitió verificar la codificación diagnóstica y obtener datos detallados sobre causa, mecanismo, características y severidad del trauma, así como variables clínicas como frecuencia cardíaca, frecuencia respiratoria, presión arterial, ECG y otras necesarias para calcular las escalas de clasificación del trauma evaluadas en el estudio.

Verificación de hallazgos complementarios

Los hallazgos radiológicos e intraoperatorios (de las cirugías) fueron verificados manualmente a partir de los informes correspondientes, con el fin de asegurar la precisión y validez de los datos utilizados en el análisis.

Variable principal de resultado

La variable principal de resultado fue la mortalidad al egreso, medida a los 30 días de hospitalización o antes si falleció o fue dado de alta a su casa (en este caso resultado = vivo).

Control de calidad de los datos

Se implementaron medidas de aseguramiento y control de calidad antes, durante y después del proceso de recolección de datos. Una muestra aleatoria del 15% de los registros fue sometida a un proceso de doble verificación, mediante el cual dos investigadores independientes validaron la información y conciliaron cualquier discrepancia detectada.

Métodos estadísticos

Las variables categóricas se presentaron como frecuencias y proporciones, y se compararon entre los grupos de sobrevivientes y fallecidos mediante la prueba de chi-cuadrado con corrección de Yates por continuidad. Las variables continuas se expresaron como mediana y rango intercuartílico (RIC), y las comparaciones entre grupos se realizaron utilizando la prueba de Wilcoxon-Mann-Whitney.

Se evaluó el desempeño de las escalas en términos de su capacidad predictiva de supervivencia. Para ello, se construyó un modelo de regresión logística por separado para cada escala, en el cual la variable dependiente (desenlace) fue el estado vital al egreso, considerado como una variable dicotómica (vivo/muerto), y la variable independiente (predictora), fue la escala de trauma correspondiente. Posteriormente, se analizó el desempeño de cada modelo mediante medidas de discriminación y calibración.

La discriminación se evaluó a través del área bajo la curva característica operativa del receptor (AUROC), que cuantifica la capacidad del modelo para diferenciar entre sobrevivientes y fallecidos; un valor de 1 indica una discriminación perfecta, mientras que un valor de 0,5 refleja una capacidad predictiva equivalente al azar. La calibración se valoró mediante la prueba de bondad de ajuste de Hosmer-Lemeshow, la cual examina la concordancia entre las probabilidades observadas y predichas por el modelo; un valor de $p > 0{,}05$ se interpreta como indicativo de una buena calibración, al no rechazarse la hipótesis nula del buen ajuste del modelo (55).

El cálculo del tamaño muestral se realizó utilizando una fórmula para la comparación de proporciones. Se estimó una muestra requerida de 927 niños para identificar una diferencia del 2% entre la mortalidad esperada y la observada, con un nivel de significancia del 5% y un poder estadístico del 80%.

El estudio se llevó a cabo siguiendo las directrices de Strengthening the Reporting of Observational Studies in Epidemiology (STROBE). El análisis estadístico se realizó con Stata® versión 17 (StataCorp, College Station, Texas, EE. UU.).

Una vez descritos los aspectos metodológicos comunes a los tres estudios que conforman esta tesis, a continuación, se presenta la metodología específica aplicada en cada uno de éstos. Cada estudio corresponde a uno de los artículos publicados en el compendio y se enfoca en la evaluación del desempeño de una escala de clasificación del trauma. Se describen de manera individual el diseño particular, las variables analizadas y los procedimientos estadísticos utilizados en cada caso.

3.2 Metodología especifica de los estudios

Pediatric Trauma Score (PTS)

Para todos los pacientes incluidos en el estudio se calculó el PTS, y se comparó entre sobrevivientes y fallecidos. Posteriormente, se desarrolló un modelo de regresión logística simple, en el que el PTS se utilizó como variable predictora y la mortalidad al egreso (vivo versus fallecido) como variable de desenlace. El desempeño del modelo se evaluó mediante análisis de discriminación, utilizando el área bajo la curva característica operativa del receptor (AUROC), y mediante análisis de calibración, a través de la prueba de bondad de ajuste de Hosmer-Lemeshow.

International Classification of Diseases, 10th Revision (ICD-10)-based Injury Severity Score (ICISS):

Se calculó para todos los pacientes del estudio y se comparó entre sobrevivientes y fallecidos. Se desarrollaron dos modelos de regresión logística. El primer modelo incluyó solo ICISS como variable independiente y el estado vital al egreso (vivo o fallecido) como variable dicotómica de desenlace. El segundo modelo incorporó además de ICISS, la ECG, quedando así este modelo con dos variables predictoras, ambas de carácter cuantitativo continuo.

El desempeño de ambos modelos se evaluó mediante discriminación con AUROC, y calibración, a través de la prueba de bondad de ajuste de Hosmer- Lemeshow. Se comparó el desempeño de ambos modelos a través del Criterio de Información de Akaike (AIC) (56) y el Criterio de

Información Bayesiano (BIC) (57,58), donde valores más bajos indican un mejor modelo. También se realizó una comparación estadística gráfica de las curvas ROC de ambos modelos utilizando la prueba de DeLong (56) y se analizó la significancia estadística de la diferencia observada entre ambas curvas, considerando una $p < 0,05$ significativamente diferente.

Trauma and Injury Severity Score (TRISS)

Se calcularon los puntajes de ISS (que forma parte de TRISS) y TRISS para los pacientes con información completa, y se compararon entre sobrevivientes y fallecidos. Se desarrollaron dos modelos de regresión logística. El primero utilizó el TRISS original como variable predictora y el estado vital al egreso como variable de desenlace.

Para la construcción del nuevo modelo, se estimaron nuevos coeficientes para las variables RTS, ISS y edad (variables de la ecuación para el cálculo de TRISS) mediante regresión logística, considerando la edad como una variable continua. A partir de estos coeficientes, se recalculó el puntaje TRISS, generando una nueva versión adaptada denominada Peds-TRISS. Esto contrasta con la versión original de TRISS, que excluye la edad del modelo en pacientes pediátricos.

Comparamos los modelos Peds-TRISS y el TRISS original utilizando los criterios AIC y el BIC y realizamos una comparación estadística gráfica de las curvas ROC de ambos modelos mediante la prueba de DeLong (56).

Validación Interna de los nuevos modelos

Tratándose de nuevos modelos predictivos, siguiendo las recomendaciones TRIPOD (Transparent Reporting of a multivariable prediction model for Individual Prognosis or Diagnosis) (59), se realizó una validación interna de ambos modelos mediante la herramienta estadística de remuestreo Bootstrap, una técnica potente y eficiente que proporciona estimaciones más estables y menos sesgadas del rendimiento de modelos, ampliamente reconocida en la investigación de modelos predictivos (59-62). Se utilizaron 500 remuestreos para reducir la incertidumbre y proporcionar estabilidad y consistencia a los resultados (63).

Las medidas de rendimiento de la validación interna fueron la discriminación con el estadístico C, la calibración mediante calibration-in-the-large (CITL, valor ideal de 0), la pendiente de calibración (valor ideal de 1) y la razón observada: esperada (razón E:O, valor ideal de 1) (55,61).

Evaluación comparativa de resultados

Entre las herramientas de evaluación de resultados y control de calidad se encuentran los métodos estadísticos DEF (DEFinitive outcome-based evaluation), utilizados internacionalmente para comparar las tasas de supervivencia o mortalidad por traumatismo entre dos instituciones (36,64-66). Incluyen los estadísticos Z y W El estadístico Z, descrito inicialmente por Flora en 1978 (67), compara la supervivencia observada en un grupo de pacientes con la supervivencia prevista según el grupo de referencia (MTOS) y cuantifica la diferencia (36). La fórmula es:

$$Z = \frac{S - \sum Pi}{\sqrt{(\sum PiQi)}}$$

Donde: S = supervivientes observados, ΣPi = suma de las probabilidades de supervivencia esperadas, Qi = probabilidad de muerte (1-Pi), ΣPiQi = suma del producto de las probabilidades de supervivencia y muerte (36). Un valor Z entre −1,96 y +1,96 no es estadísticamente significativo, lo que significa que no hay evidencia de que el grupo evaluado tenga una tasa de supervivencia significativamente diferente a la de referencia, con un nivel de significancia de 0,05 (36,67).

Para que sea válido, Pi y Qi deben tener un valor mínimo de 5 (67). Dado que el valor Z puede verse afectado por las diferencias en la severidad de las lesiones entre los grupos de comparación, el estadístico M mide la comparabilidad entre grupos. Para calcularlo, la probabilidad de supervivencia se divide en seis rangos y se compara la fracción de pacientes en cada rango entre ambos grupos, cuantificando sus diferencias. Su fórmula es: M = S1 + S2 + S3 + S4 + S5 + S6, donde S es el valor mínimo entre ambos grupos en cada rango. Un valor de M entre 0,88 y 1 indica que ambos grupos son similares (36).

Nosotros utilizamos este método de evaluación comparativa analizando la supervivencia como desenlace.

4. RESULTADOS

Los resultados comprenden los artículos publicados.

Artículo 1:

Título; Performance of the Paediatric Trauma Score on survival prediction of injured children at a major trauma centre: A retrospective Colombian cohort, 2011−2019

Autores: Ana De los Ríos-Perez, Alberto García, Laura Cuello, Sara Rebolledo, Andrés Fandiño-Losada

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*Q1 en categoría: Salud Publica, ambiental y ocupacional

Resumen:

Background: Despite improvements in children's health due to a reduction in infections, trauma continues to cause many deaths among adolescents. Strategies to mitigate morbidity and mortality from trauma include severity scores to classify and refer patients to the appropriate hospitals to provide better management; however, these strategies have not been assessed in Colombian children. This study aimed to describe the characteristics and outcomes of injured children and evaluate the

performance of the PTS in predicting survival at a major trauma centre in a Colombian city.

Methods: This was a retrospective cohort study of children aged <18 years who were treated for injuries at a hospital in Colombia. The primary outcome was 30-day mortality. A simple logistic regression model was used with PTS as the predictor variable and vital status at discharge as the outcome variable. PTS performance was assessed by discrimination using the area under the receiver-operating characteristic (AUROC) curve and by calibration using the Hosmer-Lemeshow (HL) goodness-of-fit test.

Findings: A total of 1047 children were admitted. The median age was 12 years (interquartile range [IQR]=5−15); 73.7% were male, and 66.1% had blunt trauma. The most frequent cause of injury was traffic accident (31.5%) followed by assaults (29%). Mortality was 5.9%; 61.3% of these deaths occurred in adolescents between 15 and 17 years of age and 71% of deaths in this age group were due to injuries from a firearm. The PTS had a median of 7 (IQR=5−9), an AUROC of 0.93, and good calibration (HL=7.97, $p = 0.33$).

Interpretation: The highest proportion of trauma and death occurred among adolescents. Interpersonal violence was the most frequent cause of death in this age group. The PTS showed good predictive power for survival, with excellent discrimination and good calibration.

Performance of the Paediatric Trauma Score on survival prediction of injured children at a major trauma centre: A retrospective Colombian cohort, 2011−2019

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Summary

Background Despite improvements in children's health due to a reduction in infections, trauma continues to cause many deaths among adolescents. Strategies to mitigate morbidity and mortality from trauma include severity scores to classify and refer patients to the appropriate hospitals to provide better management; however, these strategies have not been assessed in Colombian children. This study aimed to describe the characteristics and outcomes of injured children and evaluate the performance of the Pediatric Trauma Score (PTS) in predicting survival at a major trauma centre in a Colombian city.

Methods This was a retrospective cohort study of children aged <18 years who were treated for injuries at a hospital in Colombia. The primary outcome was 30-day mortality. A simple logistic regression model was used with PTS as the predictor variable and vital status at discharge as the outcome variable. PTS performance was assessed by discrimination using the area under the receiver-operating characteristic (AUROC) curve and by calibration using the Hosmer-Lemeshow (HL) goodness-of-fit test.

Findings A total of 1047 children were admitted. The median age was 12 years (interquartile range [IQR]=5−15); 73·7% were male, and 66·1% had blunt trauma. The most frequent cause of injury was traffic accident (31·5%) followed by assaults (29%). Mortality was 5·9%; 61·3% of these deaths occurred in adolescents between 15 and 17 years of age and 71% of deaths in this age group were due to injuries from a firearm. The PTS had a median of 7 (IQR=5−9), an AUROC of 0·93, and good calibration (HL=7·97, $p = 0·33$).

Interpretation The highest proportion of trauma and death occurred among adolescents. Interpersonal violence was the most frequent cause of death in this age group. The PTS showed good predictive power for survival, with excellent discrimination and good calibration.

Funding None.

Keywords: Injuries; Paediatric trauma; Trauma severity indices; Trauma score; Pediatric trauma score; Mortality; Survival prediction

Introduction

According to the Global Burden of Disease Study, the health of the population worldwide has improved; however, this improvement has been modest in children older than 10 years, in whom injuries continue to be the leading cause of death and disability.[1,2] Injuries cause more years of potential life to be lost before 18 years

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Research in context

Evidence before this study

This study was conducted in 2019. Before its initiation, a PubMed search was conducted using the search terms ("Pediatrics"[Mesh] OR pediatric* OR child*) AND (trauma OR injur*) AND ("survival prediction") without language or year of publication restrictions. No study has assessed the prediction of survival in injured children or the performance of PTS in their care in Latin America. Few studies on paediatric trauma were found from Colombia; most descriptive and used a combination of adult and paediatric subjects, and none applied trauma scores in children. We repeated the search in July 2021, and again found no publications in Latin America.

Added value of this study

Research on paediatric trauma in Colombia is scarce, limiting the availability of data to enable the proposal of intervention strategies that mitigate the incidence of trauma and its devastating consequences. This study contributes to scientific evidence in Colombia and Latin America and is one of the region's largest cohorts of paediatric trauma studies. Unlike most studies reported worldwide, this study showed a significant degree of firearm violence among adolescents; firearm violence was the leading cause of death. Therefore, firearm violence is a relevant public health problem that requires intersectoral interventions. Results also showed that a high proportion of children were referred from other hospitals with insufficient resources and training, suggesting an opportunity for intervention in prehospital care in both the initial approach of the injured child and their transfer from the scene to the appropriate hospital for continued health care. Most studies on paediatric trauma in this region have been descriptive. Our study is the first in Colombia and Latin America to assess survival prediction in children with trauma using the PTS. Although international authorities have historically recommended the use of PTS in the injured, it is not routinely used in our healthcare settings; consequently, children are not transferred from trauma sites with objective criteria such as severity classification. Rather, criteria upon transfer are subjective or administrative, delaying the definitive care of more seriously injured patients.

Implications of all the available evidence

Our results showing that high levels of violence are the leading cause of death among adolescents will facilitate the proposal of multidisciplinary and intersectoral intervention strategies of a preventive nature. The findings support the systematic use of PTS in the care of injured children, thereby optimising their transfer to the appropriate hospital. This prevents wasting of the resources of large centres in the care of trivial injuries or delaying the care of seriously injured children in centres with insufficient resources, directly affecting patient outcomes.

than sudden infant death, cancer and infectious diseases combined.[3] Unintentional injuries are the second leading cause of death after 5 years of age, and intentional injuries are the third leading cause after 15 years.[1] In Colombia, violence is the leading cause of death after 5 years of age.[4] These high injury rates represent a severe public health problem requiring multisectoral collaborative efforts, and are an evident opportunity for preventative injury intervention. However, when prevention fails, the next opportunity for intervention is to provide optimal care for the injured to impact their survival favourably with the fewest sequelae possible. Strategies such as using trauma scores have been proposed; such scores have existed for more than 40 years and have shown variable performance results. Nonetheless, each scoring system has particular benefits that must be considered, along with the ease of application and availability of the resources necessary to calculate the scores.[5] Trauma scores have prognostic utility, standardise the language used by different professionals (prehospital healthcare workers, emergency physicians, intensivists, surgeons, traumatologists, epidemiologists, and researchers), allow interhospital comparisons, and improve resource planning by providing information about patient severity. The Pediatric Trauma Score (PTS), designed for children, is an available trauma scoring tool. The American College of Surgeons Committee on Trauma (ACS COT) in Advanced Trauma Life Support has highlighted the PTS as a helpful tool for the initial approach to paediatric trauma.[6] Its performance has not been assessed in Colombia, a region with trauma characteristics and care systems that differ from the United States, where the score was developed. The present study is the first in Colombia and Latin America to evaluate the ability of the PTS to predict survival in injured children. This study also aimed to describe the trauma characteristics and outcomes of the assessed children.

Methods

Study design and setting

This was an analytical observational study of a retrospective cohort of children admitted between January 2011 and May 2019 to the emergency room of Fundación Valle del Lili University Hospital in Cali, Colombia. Initially, the study period was proposed until December 2018; however, the period was extended until May 2019 to achieve an optimal sample size.

The study hospital has 523 beds; 205 are in the intensive care unit. The hospital treats highly complex pathologies, including severe trauma, and is equivalent to a major trauma centre. Colombia is a country in northern South America, with 48,258,494 inhabitants.[7] According to the World Bank classification, the country is categorised as a medium-high income country.[8] Cali is a city in the southwestern region with 2,496,442 inhabitants.[9]

The study protocol was approved by the hospital's Biomedical Research Ethics Committee under registration number 295–2018.

Participants

Participants included children under 18 years of age who presented to the emergency room with a trauma diagnosis (International Classification of Diseases, 10th edition, discharge codes between S00 and T149) and required hospitalisation consisting of a stay longer than 6 h or death before that time. Patients were excluded if they had burns, were involved in a drowning accident, were diagnosed as having a foreign body, or were intoxicated. Further exclusions included if more than 24 h had elapsed since the trauma, if they were transferred to another hospital before day 30 of hospitalisation due to the impossibility of verifying their vital status at that time, or if they were transferred from provinces other than Valle del Cauca or Cauca. In addition, patients were excluded if they had haematological, oncological, metabolic, or osteopathic comorbidities that could influence the approach or outcome, or if they had undergone surgical interventions at another institution due to the impossibility of classifying their initial lesions; therefore, trauma scores could not be calculated which could lead to an erroneous classification of individuals (Figure 1).

Data sources and measurement

The clinical registries of the included patients were reviewed; diagnostic coding was verified, sociodemographic information, the mechanism and cause of trauma, and the type and severity of injuries were obtained, and radiology reports were reviewed. Trauma time was defined as the time elapsed between injury and hospital admission. This information was collected from the patient's clinical history which included the date and time of the injury. Clinical variables such as heart rate, respiratory rate, blood pressure, Glasgow Coma Scale score, and the variables necessary to calculate the PTS, among others, were obtained. The primary outcome variable was mortality at discharge, measured on day 30 of hospitalisation or earlier if the patient died or was discharged home. We considered surgery, blood transfusion, and intensive care as secondary outcome variables. The predictor variable was the PTS. The injury severity score (ISS), a score widely used by trauma researchers, was calculated and compared between living and dead patients and included in the analysis.[10]

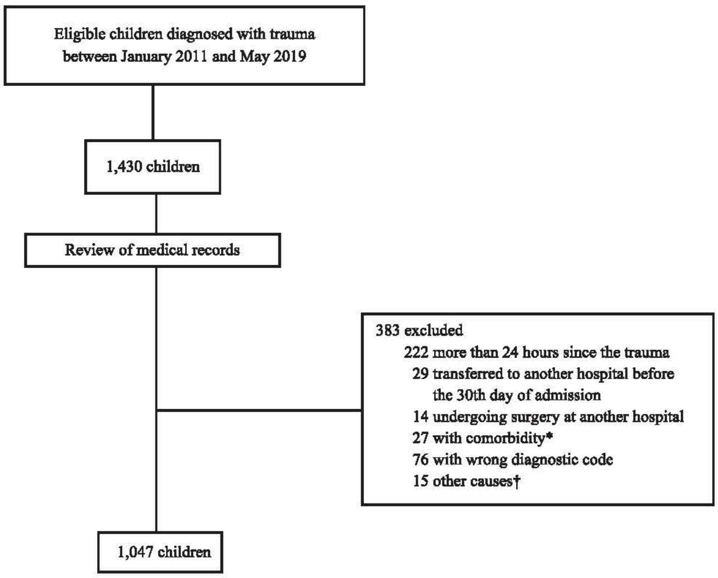

Figure 1. Participant flow chart.
*Haematological, oncological, metabolic, or osteopathic comorbidities.
†Other causes: unknown time since trauma, escape, transfer from provinces other than Valle del Cauca or Cauca.

The direct cause of death was determined from death certificates and verified by reviewing the patients' clinical registries.

Pediatric trauma score

The PTS was described in 1987 by Tepas et al.[11] Its application in children combines physiological and anatomical variables—weight, airway status, systolic blood pressure, central nervous system status, fractures, and wounds—to classify the severity of the injury. The tool yields a score between -6 and +12, with lower scores indicating greater severity. A score ≤8 suggests that the patient should be transferred to a trauma centre because of a significantly increased risk of mortality.[12]

Injury severity score

The ISS was first described in 1974 as the sum of the squares of the three highest Abbreviated Injury Scale (AIS) scores between different body areas.[13] A score of 16 or more has traditionally been established as a severe injury.[10] The AIS, necessary to calculate the ISS, was described in 1971, and its score ranges from 0 to 6, with 3 being a severe injury and 6 being the worst injury.[14]

Statistical methods

Categorical variables are presented as frequencies and proportions and were compared between survivors and deceased using either a chi-square or Fisher's exact test, as appropriate. Continuous variables are presented as the mean and standard deviation or median and interquartile range (IQR) according to the normality of their distribution. Variables were compared between the deceased and survivors using the Student's t-test or Wilcoxon-Mann-Whitney sum of ranges, as appropriate. The performance of PTS in predicting survival was evaluated using a simple logistic regression model, considering PTS as a predictor variable and vital status at discharge (alive or dead) as a dichotomous outcome variable, with the application of statistical tools such as discrimination and calibration. Discrimination using the area under the receiver-operating characteristic (AUROC) curve accurately demonstrates the ability of the score to predict survival, with a value of 1 indicating perfect discrimination and a value of 0·5, a predictive capacity that is not superior to chance. Calibration was assessed using the Hosmer-Lemeshow goodness-of-fit test, which measures the agreement between the observed probability of survival and that predicted by the model, indicating $p > 0{\cdot}05$ as a good calibration.[15]

We hypothesised a good discriminative capacity with an ROC curve greater than 0·9 and a good fit between observed and expected mortality with a goodness of fit of $p > 0{\cdot}05$. The sample size was calculated using a proportional-comparison formula. The a priori estimated sample size was 1043 children, which was estimated to detect

	n = 1047
Median age, years (p25 to p75)	12 (5–15)
Age groups	
0–4 years	221 (21·1%)
5–9 years	229 (21·9%)
10–14 years	249 (23·8%)
15–17 years	348 (33·2%)
Sex	
Male	772 (73·7%)
Female	275 (26·3%)
Payor status	
Private insurance	692 (66%)
Subsidised	355 (34%)
Origin (province)	
Valle del Cauca	775 (74%)
Cauca	272 (26%)
Transportation[a]	
Ambulance	791 (76·1%)
Private/not ambulance	248 (23·9%)
Transferred from another hospital[b]	
Yes	725 (70%)
No	311 (30%)
Mechanism of injury	
Blunt	692 (66·1%)
Penetrating	355 (33·9%)
Cause of injury	
Traffic accident	330 (31·5%)
Assault	304 (29%)
Firearm	224
Stabbing	59
Hit by/against something	13
War explosive	8
Fall	297 (28·4%)
Other	110 (10·5%)
Unknown	6 (0·6%)
Age-adjusted hypotension	
Yes	74 (7%)
No	973 (93%)
Glasgow Coma Scale[c]	
13–15	790 (78%)
9–12	79 (7·8%)
3–8	144 (14·2%)
PTS, median (p25 to p75)	7 (5–9)
ISS, median (p25 to p75)	9 (5–17)
ICU	
Yes	521 (49·8%)
No	526 (50·2%)
Blood transfusion	
Yes	265 (25·3%)
No	782 (74·7%)
Surgery	
Yes	649 (62%)
No	398 (38%)
Hospital stay, median (p25 to p75)	3·5 (1·7–6·9)
Mortality	62 (5·9%)

Table 1: **Sociodemographic and clinical characteristics of the children.**
Data are *n* (%) or median (p25 to p75). PTS=pediatric trauma score. ISS=injury severity score. ICU=intensive care unit.
[a] Data were available for 1039 patients.
[b] Data were available for 1036 patients.
[c] Data were available for 1013 patients.

a difference of 2% between observed and expected mortality (two-sided 5% significance, power 90%).

The analyses were performed using Stata® version 16.1 (StataCorp, College Station, Texas 77845, USA).

Role of the funding source

There was no funding source for this study. All authors had full access to the study data and final responsibility for the decision to submit for publication.

Results

Between January 2011 and May 2019, 1047 children aged <18 years were admitted to the emergency room and fit the criteria to be included in the study. Among those excluded, 29 (2·7%) were transferred to hospitals of a lower level of complexity before the 30th day of hospitalisation. These patients were excluded because their vital status could not be verified at discharge. Reasons for transferring a patient before 30 days of hospitalisation were related to administrative issues affecting the completion of treatment. Thus, 29 patients, considered a low proportion, were transferred with no 30-day survival data. However, these patients likely were alive and thus would have a minimal effect on survival estimates.

The median age was 12 years (IQR, 5–15 years), and 73·7% were male. Colombia's subsidised health insurance system covered 34% of the total, and the remaining 66% was covered by the contributory health insurance system (private insurance). The injury mechanisms were blunt (66·1%) and penetrating (33·9%). The most common causes of injury were traffic accidents and assaults, accounting for 31·5% and 29%, respectively; the former was more frequent in children under 10 years of age, and the latter was more frequent after 10 years of age. The median PTS was 7 (IQR, 5–9). The mortality rate was 5·9% (Table 1); mortality occurred in the first 24 h in 67% of cases, and the median was 15 h (IQR 3·8 –49) (Figure 2) without deaths after day 20 of hospitalisation. Cranioencephalic trauma was the most frequent cause of death (Table 2). Sixty-one and three tenths percent of the deaths were due to intentional trauma, with firearms caused 95% of these deaths. Table 2 shows the cause of death according to the anatomical location and intentionality of injury.

Regarding the secondary outcome variables, 62% underwent surgery, 49·8% were admitted to the ICU, and 25·3% received a blood transfusion.

For bivariate analysis, the patients were classified according to their vital status at discharge (Table 3).

Eighty-four percent of the deceased patients were between 10 and 17 years of age, and 71% of them died due to an assault. Most deceased patients were adolescent males with a lower ability to pay, penetrating trauma, admitted in a coma (Glasgow median, 3), with a median PTS of 0, and a median ISS of 31 (severe trauma). Almost 25% were admitted to the hospital in a state of decompensated shock (hypotension adjusted for age), indicating a state of extreme severity, with death occurring within the first hour after admission (median, 60 min; IQR, 45–94 min). In this group of dead children, 51·6% underwent surgery, 53·2%

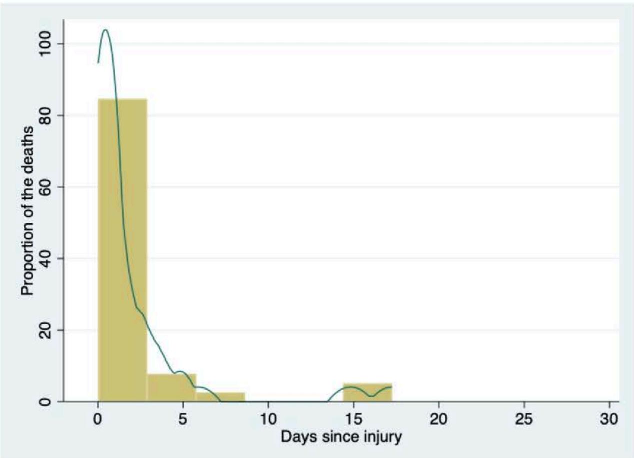

Figure 2. Mortality timing.
Mortality was measured on day 30 of hospitalisation or earlier if the patient died or was discharged home. Data were available for 815 patients.

	Head	Chest	Abdomen	Thoracoabdominal
Unintentional	20	1	1	1
Intentional	32	1	2	3
Indeterminate	1			

***Table 2*: Cause of death according to intentionality and anatomical site of the injury.**
Data are *n*.

	Alive (*n* = 985)	Dead (*n* = 62)	*p* value
Median age, years (p25 to p75)	11 (5–15)	15 (13–17)	<0·0001
Age groups			<0·0001
0–4 years	215 (21·8%)	6 (9·7%)	
5–9 years	225 (22·8%)	4 (6·4%)	
10–14 years	235 (23·9%)	14 (22·6%)	
15–17 years	310 (31·5%)	38 (61·3%)	
Sex			0.03
Male	719 (73%)	53 (85·5%)	
Female	266 (27%)	9 (14·5%)	
Payor status			<0·0001
Private insurance	667 (67·7%)	25 (40·3%)	
Subsidised	318 (32·3%)	37 (59·7%)	
Origin			0·24
Valle	733 (74·4%)	42 (67·7%)	
Cauca	252 (25·6%)	20 (32·3%)	
Transferred from another hospital[a]	672 (69%)	53 (87%)	
Mechanism of injury			<0·0001
Blunt	667 (67·7%)	25 (40·3%)	
Penetrating	318 (32·3%)	37 (59·7%)	
Age-adjusted hypotension	59 (6%)	15 (24·2%)	<0·0001
Glasgow Coma Scale, median (p25 to p75)[b]	15 (14–15)	3 (3–6)	<0·0001
PTS, median (p25 to p75)	8 (5–9)	0 (0–1)	<0·0001
ISS, median (p25 to p75)	9 (4–16)	31 (25–37)	<0·0001
ICU			<0·0001
Yes	470 (47·7%)	51 (82·3%)	
No	515 (52·3%)	11 (17·7%)	
Blood transfusion			<0·0001
Yes	232 (23·6%)	33 (53·2%)	
No	753 (76·4%)	29 (46·8%)	0·08
Surgery			
Yes	617 (62·6%)	32 (51·6%)	
No	368 (37·4%)	30 (48·4%)	<0·0001

***Table 3*: Bivariate analysis: characteristics of patients by vital status at discharge.**
Data are *n* (%) or median (p25 to p75). PTS=pediatric trauma score. ISS=injury severity score. ICU=intensive care unit.
[a] Data were available for 1036 patients.
[b] Data were available for 1013 patients.

received a blood transfusion, and 82·3% were admitted to the ICU since the remaining percentage died before ICU admission.

We found 689 (66%) patients with a PTS ≤8 and 358 with a PTS >8. The performance of the PTS showed an AUROC of 0·93 (95% CI 0·89 to 0·96; $p < 0·0001$) (Table 4; appendix p 2) and Hosmer–Lemeshow goodness of fit of 7·97 ($p = 0·33$; Table 4), indicating excellent discrimination and good calibration, respectively, and a performance that was maintained for the different injury mechanisms (blunt or penetrating) (Table 4). Given the classic PTS cut-off point of 8 as the value from which mortality increases significantly, we evaluated the performance of the PTS by categorising

	OR	p value	95% CI	AUROC	HL	Prob > X2
PTS						
Complete cohort (n = 1047)	1·8	<0·0001	1·61–2·02	0·93	7·97	0·33
Blunt trauma (n = 692)	1·68	<0·0001	1·44–1·95	0·91	3·19	0·87
Penetrating trauma (n = 355)	1·9	<0·0001	1·59–2·28	0·93	8·72	0·12

***Table 4*: Performance of Pediatric Trauma Score by the mechanism of injury.**
OR=odds ratio, CI=confidence interval, AUROC=area under the receiver-operating characteristic curve, HL=Hosmer–Lemeshow.

its score, observing an AUROC of 0·92 (95% CI 0·89–0·94) in those with PTS ≤8 and 0·74 (95% CI 0·71–0·76) in those with a PTS >8. We "rescued" the predictive capacity in children with a worse score for whom referral to the appropriate hospital is a priority because of their high probability of dying. An additional analysis was done to evaluate the performance of the PTS according to age and the presence of severe head injury (Appendix p 3).

Discussion

This study presents data on the frequency, severity, and characteristics of trauma in a paediatric sample in Colombia. Traffic accidents and assaults were the most frequent causes of injury. The results regarding traffic accidents are in accordance with existing evidence from other researchers worldwide[16–20] and within the region.[21,22] These injuries are potentially preventable with the implementation or optimisation of adequate, exhaustive, and strong prevention measures linked to a solid and robust surveillance system. Notably, reported deaths in our study were predominantly intentional and caused by firearms, which contrasts with studies reporting that deaths due to trauma were mostly unintentional.[1] We also observed that most of the deceased children had severe cranioencephalic trauma and that death occurred quickly, similar to studies that analysed trauma mortality.[23] The proportion of deceased who did not receive surgery or require admission to the ICU was attributed to the extreme severity of their admission status, with rapid progression to brain death and death. Although mortality from injuries has decreased worldwide, injuries remain among the leading causes of death,[1] and many young lives continue to be lost. In Colombia, violence is the leading cause of death after 5 years of age[4]; this is a serious and critical social problem and of major concern considering that these victims are children. These deaths are "the tip of the iceberg" as more injured children survive but require hospital care or are left with disabilities.[16] The considerable percentage of hospitalised patients who were transferred from hospitals with a lower level of complexity, mainly those who died, is a noteworthy finding of our study. We do not have information on the treatment received in the originating hospitals; however, the patient status upon arrival included coma and median PTS and ISS scores of 0 and 31, respectively, values with a high mortality rate.[12,24] Furthermore, a proportion of them arrived hypotensive, which in children is considered a terminal situation with increased mortality[25]; therefore, it is crucial to receive the required care in the shortest time possible. These critical patients should be transferred directly from the injury site to a major trauma centre because the risk of imminent death is high without adequate care and timely intervention.[26,27]

The proportion of violent trauma evidenced in this study represents a serious public health problem that must be addressed with investment and combined efforts at the local, international and intersectoral levels.[28] Such efforts include those proposed by the World Health Organization (WHO) in collaboration with the United States Centers for Disease Control and Prevention (US CDC), the Pan American Health Organization (PAHO), and the United Nations Children's Fund (UNICEF), among other organisations, with the implementation of the INSPIRE strategies for preventing violence against children.[29] Although the prevention of injuries is an ideal concept, injuries do occur despite the best preventive efforts, and physicians must be prepared to treat them accordingly. One strategy with demonstrated value is the use of trauma scores[30] that objectively classify patients and facilitate routing to an appropriate trauma centre; such scores have been used in paediatrics since the 1980s. However, their performance in survival prediction has not been evaluated in Latin America. The PTS was designed in a developed country (United States), with social characteristics different from those of our country, as well as an organised road infrastructure, a more specialised, structured and coordinated health and trauma care system, and trauma characteristics different from those of our environment. Additionally, the PTS has been implemented for several decades, during which time there have been progressive technological developments and the creation of particular protocols for caring for injured patients. It was important to assess the effectiveness of the PTS in our environment. We found that the PTS was considerably lower in deceased patients. The critical value at which infant mortality has traditionally been considered to increase was reported by Tepas as 8.[12] However, in our study, we evaluated the cut-off point in the ROC curve with greater sensitivity and specificity, finding this threshold at 4, very different than the threshold proposed by Tepas.[12] A study by Orliaguet et al.[31] had similar results to ours. Like our study, their study used ROC curves, one of the statistical tools with greater diagnostic accuracy in this type of analysis.[32,33] We evaluated the capacity of the scoring tool to predict survival, finding an excellent performance in both discrimination and calibration, which has also been demonstrated by researchers in other countries.[17,31,34–36] Other studies, such as that of Yoon et al.[37] reported that although the performance of the PTS was good, it was lower than that of other scores such as the BIG score (composed of the base deficit [B], International normalized ratio [I], Glasgow Coma Scale [G]). However, those scores require laboratory tests, resulting in additional time waiting for results or a complex calculation in some contexts. Furthermore, it may not be available at all levels of care or in the prehospital setting. There are several reasons for the good performance of the PTS found in our study. First, PTS combines anatomical and physiological factors, including weight, among its variables, recognising that the severity of injuries and responses differ depending on age or body size.[5,38] Second, PTS evaluates the central nervous system, which is of great relevance because with multisystem involvement as often occurs with severe trauma, the level of consciousness is one of the main signs of hypoperfusion and haemodynamic instability that occurs even before hypotension. Third, as an element of quality control, the PTS makes it possible to identify deaths with less severe injuries, in which handling errors could have occurred. However, the current study did not address the characteristics of the treatment received as this was not part of the stated objectives. Added to these strengths is the ease of calculation of the PTS in both prehospital and in-hospital settings by medical or non-medical health personnel. In addition to its good results, it is reasonable to systematically include PTS in the care for injured children, as the American College of Surgeons recommends in its Advanced Trauma Life Support (ATLS) manual.[6] The PTS quantifies the severity of trauma, supports efficient resource allocation and use for the care of injured children and the dissemination of data and experiences in hospitals, and generates scientific evidence that objectively helps in public health decision-making. With its use, we, as healthcare providers in our country, could contribute to and align ourselves with the Global Strategy for the Health of Women, Children, and Adolescents, which seeks, among other objectives, to reduce preventable mortality and improve health for children and adolescents by 2030.[39]

This study had the following limitations. The study was retrospective with inherent limitations. We did not have information about prehospital care, the treatment received before arrival at our hospital, or the specific circumstances under which the trauma occurred, such as the use of safety measures in traffic accidents. The study was monocentric, which limits the generalisability of the results. Including other geographical contexts implies collaborative inter-institutional efforts, but gives us privileged information, which will be interesting to consider in the future. Regarding the strengths of our study, the sample size was appropriate compared to other studies on paediatric trauma in the region and included a significant proportion of patients with violent trauma, which is low in most paediatric studies.

In conclusion, most deaths in this study were caused by intentional trauma (violence), and firearms were used in almost all deaths. Cranioencephalic trauma was the leading cause of death. PTS showed an excellent ability to predict survival, regardless of the mechanism of injury. Prospective studies are needed; ideally, these would include the analysis of regional trauma records to allow epidemiological surveillance at the hospital level. Such studies would complement the surveillance carried out by government entities, and thus reduce the knowledge gap and enhance planning strategies that would impact the health and well-being of children.

Contributors

ADlR-P, AG and AF-L contributed to the conceptualisation, methodology, statistical analysis, and interpretation of data and administered the project. ADlR-P did the data curation and wrote the original draft. AG and AF-L provided academic resources, supervised the project, and validated the data. LC and SR contributed to data collection and wrote different draft versions. All authors had full access to all of the data, critically reviewed and approved the manuscript's final version, and had final responsibility for the decision to submit for publication.

Data sharing statement

According to the Helsinki Declaration, the datasets generated and analysed during the current study are not publicly available to protect the rights of research participants. However, these are available from the corresponding author upon reasonable request.

Declaration of interests

We declare no competing interests.

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Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.lana.2022.100312.

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<u>Artículo 2:</u>

Título; Quality of pediatric trauma care: development of an age-adjusted TRISS model and survival benchmarking in a major trauma center

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Resumen:

Background: Pediatric trauma is a major global health concern, accounting for a substantial proportion of deaths and disease burden from age 5 onwards. Effective triage and management are essential in pediatric trauma care, and prediction models such as the Trauma Injury Severity Score (TRISS) play a crucial role in estimating survival probability and guiding quality improvement. However, TRISS does not account for age-specific factors in pediatric populations, limiting its applicability to younger patients. This study aimed to modify TRISS to account for age for children (Peds-TRISS) and to evaluate its performance relative to the original TRISS. We also assessed survival outcomes to explore the model's potential utility across various clinical settings. These efforts align with quality improvement initiatives to reduce preventable mortality and supporting sustainable development goals.

Methods: This retrospective cohort study included patients under 18 years of age who were treated at a hospital in Colombia between 2011 and 2019. New coefficients for TRISS covariates were calculated using logistic regression, with age treated as a continuous variable. Model performance was evaluated based on discrimination (C statistic) and calibration, comparing Peds-TRISS with the original TRISS. Internal validation was conducted using bootstrap resampling. Survival outcomes were assessed using the M and Z statistics, which are commonly used for international trauma outcome comparisons.

Results: The study included 1,013 pediatric patients with a median age of 12 years (IQR 5–15), of whom 73% were male. The leading causes of injury were traffic accidents (31.1%), falls (28.8%), and assaults (28.7%). The overall mortality rate was 5.7%. The Peds-TRISS model demonstrated good calibration (HL = 9.7, $p = 0.3$) and discrimination (C statistic = 0.98, 95% CI 0.97–0.99), with no statistically significant difference in the ROC curve comparison with the original TRISS. Internal validation demonstrated strong performance of Peds-TRISS. The M and Z statistics were 0.93 and 0, respectively, indicating no significant differences between expected and observed survival rates.

Conclusions: Most fatalities occurred among adolescents and were due to intentional injuries. The Peds-TRISS model showed a partial

improvement in performance compared to the original TRISS, with superior results in terms of calibration, although not in discrimination. These findings highlight the potential of model customization for specific populations. Prospective, multicenter studies are recommended to further validate the model's utility across diverse settings.

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Quality of pediatric trauma care: development of an age-adjusted TRISS model and survival benchmarking in a major trauma center

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Background: Pediatric trauma is a major global health concern, accounting for a substantial proportion of deaths and disease burden from age 5 onwards. Effective triage and management are essential in pediatric trauma care, and prediction models such as the Trauma Injury Severity Score (TRISS) play a crucial role in estimating survival probability and guiding quality improvement. However, TRISS does not account for age-specific factors in pediatric populations, limiting its applicability to younger patients. This study aimed to modify TRISS to account for age for children (Peds-TRISS) and to evaluate its performance relative to the original TRISS. We also assessed survival outcomes to explore the model's potential utility across various clinical settings. These efforts align with quality improvement initiatives to reduce preventable mortality and supporting sustainable development goals.
Methods: This retrospective cohort study included patients under 18 years of age who were treated at a hospital in Colombia between 2011 and 2019. New coefficients for TRISS covariates were calculated using logistic regression, with age treated as a continuous variable. Model performance was evaluated based on discrimination (C statistic) and calibration, comparing Peds-TRISS with the original TRISS. Internal validation was conducted using bootstrap resampling. Survival outcomes were assessed using the M and Z statistics, which are commonly used for international trauma outcome comparisons.
Results: The study included 1,013 pediatric patients with a median age of 12 years (IQR 5–15), of whom 73% were male. The leading causes of injury were traffic accidents (31.1%), falls (28.8%), and assaults (28.7%). The overall mortality rate was 5.7%. The Peds-TRISS model demonstrated good calibration (HL = 9.7, $p = 0.3$) and discrimination (C statistic = 0.98, 95% CI 0.97–0.99), with no statistically significant difference in the ROC curve comparison with the original TRISS. Internal validation demonstrated strong performance of Peds-TRISS. The M and *Z* statistics were 0.93 and 0, respectively, indicating no significant differences between expected and observed survival rates.

Conclusions: Most fatalities occurred among adolescents and were due to intentional injuries. The Peds-TRISS model showed a partial improvement in performance compared to the original TRISS, with superior results in terms of calibration, although not in discrimination. These findings highlight the potential of model customization for specific populations. Prospective, multicenter studies are recommended to further validate the model's utility across diverse settings.

KEYWORDS

injuries, pediatric trauma, trauma severity indices, trauma score, TRISS, trauma injury severity score, survival prediction, quality of care

1 Introduction

Injuries among children and adolescents represent a significant global health challenge, with more than 1,600 individuals under the age of nineteen dying daily due to trauma. This burden is particularly pronounced in low- and middle-income countries, where both the incidence and impact of injuries exceed those observed in high-income regions (1, 2). Among individuals aged 5–29, 3 of the 5 leading causes of death are injury-related, including traffic accidents, falls, homicides, and suicides (3). While unintentional injuries account for the majority of these deaths globally (4), Colombia presents a distinct trauma epidemiology. In this country, interpersonal violence emerges as the leading cause of death starting at age 10 and ranks as the fourth leading cause from age 5 onward (5).

Both the World Health Organization (WHO) (6) and the Centers for Disease Control and Prevention (CDC) (7) recognize injuries as the number one killer of young people, underscoring the urgent need for effective strategies to mitigate the toll of trauma on this vulnerable population. Beyond fatalities, tens of millions of individuals worldwide suffer non-fatal injuries each year, resulting in long-term healthcare needs, rehabilitation, and substantial economic impacts due to premature death and disability (8–10).

To address this burden, international trauma care authorities emphasize strategies to improve trauma care quality and outcomes. Survival prediction models play a central role in these efforts, providing tools to estimate survival probabilities and guide clinical decision-making (11). However, while numerous prediction tools have been developed and validated for adult trauma populations, similar tools specifically tailored to pediatric trauma remain scarce. This gap is particularly concerning, given the distinct physiological and epidemiological characteristics of pediatric patients, which differ significantly from those of adults. Accurate predictive models for pediatric trauma are essential to guide clinical decision-making, improve outcomes, and address the unique needs of children.

The Trauma and Injury Severity Score (TRISS) is one of the most widely used tools in trauma centers for assessing patient survival likelihood, enabling healthcare providers to identify high-risk patients and prioritize care (12–16). Additionally, TRISS supports trauma center quality improvement by comparing observed vs. expected outcomes, facilitating benchmarking, and identifying gaps in care (17, 18). This approach aligns with the WHO's Guidelines for Trauma Quality Improvement Programmes, which advocate for strategies to reduce the burden of trauma worldwide (19).

However, TRISS was originally developed for adult populations, and its predictive accuracy is limited in pediatric patients (20, 21). This limitation arises from the model's use of age as a binary variable, which overlooks the nuanced impact of age on survival in children (22, 23). Studies have shown that modifying TRISS to treat age as a continuous variable or recalculating its coefficients can significantly enhance its predictive power for pediatric populations (24–26).

Despite these advancements, pediatric-specific adaptations of TRISS remain limited, as most survival prediction models have been optimized for adults rather than children. This issue is particularly relevant in Colombia, where the unique trauma epidemiology—characterized by high rates of violence and other trauma-related causes—emphasizes the need to test and adapt predictive tools for pediatric populations in Latin America.

In this study, we aimed to adapt TRISS to account for pediatric age as a continuous variable (Peds-TRISS) and evaluate its performance among children treated at our trauma center in Colombia. Rather than creating a new model, we focused on refining the existing TRISS framework to improve its applicability to pediatric trauma, ultimately contributing to evidence to improve quality of care and outcomes in this vulnerable population.

2 Materials and methods

2.1 Study design and setting

A retrospective study was conducted in the emergency department at Fundación Valle del Lili Hospital in Cali,

Abbreviations

ACS COT, American College of Surgeons Committee on Trauma; AIC, Akaike information criterion; AIS, abbreviated injury scale; AUROC, area under the receiver operating characteristic curve; BIC, Bayesian information criterion; CITL, calibration-in-the-large; DEF, dEFinitive outcome-based evaluation; E:O, observed: expected ratio; HL, Hosmer-Lemeshow; ICD-10, International classification of diseases, 10th edition; IQR, interquartile range; ISS, injury severity score; MTOS, major trauma outcome study; NICE, National institute for health and care excellence; Peds-TRISS, age-adjusted trauma injury severity score; RTS, revised trauma score; TRIPOD, transparent reporting of a multivariable prediction model for individual prognosis or diagnosis; TARN, trauma audit and research network; TRISS, trauma injury severity score; WHO, World Health Organization.

Colombia, between January 2011 and May 2019. Cali is served by three major trauma centers, including our hospital. Our institution operates as a Level I trauma center with 721 beds, including 250 dedicated to critical care. It handles approximately 8,000 trauma cases annually, of which 1,000 involve severely injured patients, and 700 require trauma code activation. In addition to trauma care, the hospital manages other complex pathologies and serves as a referral center for the southwestern region of the country.

2.2 Participants

Patients under 18 years old who were treated in the emergency department for trauma injuries (discharge diagnosis codes between S00 and T149, according to the International Classification of Diseases, 10th edition) were included in the review. Patients were selected if they required hospitalization, had a hospital stay longer than 6 h, or died within this period. Excluded from the study were those presenting with injuries related to drowning, burns, foreign bodies, poisoning, medical-surgical complications, or sequelae from prior trauma.

Additional exclusion criteria included patients transferred from regions outside Valle del Cauca or Cauca, those presenting more than 24 h after the trauma, and those with a history of oncological, hematological, metabolic, or osteoarticular diseases that might affect their treatment or prognosis. Patients transferred from other hospitals where they had already undergone surgery were also excluded, as this precluded accurate classification of their initial injuries and severity. Furthermore, patients transferred to another hospital before the 30th day of hospitalization were excluded due to an inability to verify their vital status at that time.

2.3 Data sources and measurement

Patient data were sourced from electronic medical records, ensuring comprehensive access to all clinical and administrative information. The chart review process involved a combination of systematic data extraction for structured fields and manual review for unstructured data. Sociodemographic variables, trauma mechanisms, causes of trauma, and injury severity were collected. Clinical variables at admission, including heart rate, respiratory rate, blood pressure, and Glasgow Coma Scale scores, were also recorded. Radiology and surgery reports were thoroughly reviewed to ensure accuracy and completeness. The primary outcome variable was mortality within 30 days of hospitalization or earlier if the patient died or was discharged home.

Information such as diagnostic codes, radiology findings, and surgery reports was manually verified to ensure completeness and accuracy. Quality control measures were applied throughout the data collection process. A random 15% sample of the collected data was subjected to a double-checking process, where two independent investigators cross-verified and reconciled discrepancies.

2.4 Trauma injury severity score (TRISS)

TRISS is a score that combines physiological and anatomical variables, and is used to estimate the probability of patient survival after in trauma. For its calculation, two scores (Revised Trauma Score-RTS and Injury Severity Score-ISS), the mechanism of injury (blunt or penetrating), and age are considered. The formula is:

$$\mathrm{Ps} = \frac{1}{1 + e^{-b}}$$

Where: Ps = probability of survival, *e* is a constant (approximately 2.718282, the base of the natural or Napierian logarithm), b = b0 + (b1xRTS) + (b2xISS) + (b3xage). Here, b0, b1, b2, and b3 are coefficients that differ according to the mechanism of the lesion, that is, if it is blunt or penetrating, and is derived from a logistic regression model based on data from the Major Trauma Outcome Study (MTOS) in North America (22, 23). The age variable is dichotomized with its coefficient being zero for those under 55 years of age, making it null in the equation for the pediatric population. For this reason, coefficients for RTS, ISS, and age were recalculated in our study, considering age as a continuous variable and accounting for the blunt or penetrating mechanism in the development of the multivariable logistic regression model, which has not been evaluated in pediatric patients in our region. The TRISS result (Ps) ranges from 0 to 1 (23) and was calculated with the new coefficients for included patients.

2.5 Revised trauma score (RTS), abbreviated injury scale (AIS) and injury severity score (ISS)

RTS accounts for three physiological variables in its formula: Glasgow Coma Scale, blood pressure, and respiratory rate, and its value ranges between 0 and 7.84 (27). The AIS serves as the basis for calculating the ISS, classifying injuries across six body regions (28). Various versions of this score have been developed; we used the 2015 version (29). The ISS is determined by summing the squares of the AIS scores for the three most severely injured regions, yielding a score between 1 and 75. An ISS of 16 or higher indicates a serious injury (30–32).

2.6 Statistical methods

Categorical variables were presented as frequencies and proportions, and comparisons between survivors and non-survivors were conducted using the chi-square test with Yates' correction for continuity. Continuous variables were presented as median and interquartile range (IQR), and comparisons between survivors and non-survivors were performed using Wilcoxon-Mann-Whitney Test. For the development of the new model, the coefficients of the RTS, ISS and Age variables were calculated using a logistic regression model, considering age as a continuous quantitative variable and the discharge status (alive/dead) as the outcome variable. The TRISS was calculated using the new coefficients (Peds-TRISS). Its performance in predicting survival was evaluated through discrimination and calibration. Discrimination assesses how well the model distinguishes between individuals who do and do not develop the outcome of interest. It was measured using the area under the receiver operating characteristic curve (AUROC), where a value of 1 indicates perfect discrimination and 0.5 indicates no better than chance. The AUROC of Peds-TRISS and original TRISS was compared using the DeLong test and the $p < 0.05$ was regarded as significantly different. Calibration, which assesses the degree of agreement between predicted and observed probabilities, was measured using the Hosmer-Lemeshow goodness-of-fit test, where a *p*-value greater than 0.05 indicates good calibration (33). We compared the Peds-TRISS and original TRISS, using the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC), where lower values indicate a better model (34, 35).

The internal validation was carried out following the Transparent Reporting of a multivariable prediction model for Individual Prognosis or Diagnosis (TRIPOD) recommendations (36). Bootstrapping resampling with 500 resamples was used, a powerful and efficient technique that provides more stable and less biased estimates of the model's performance and is widely recognized in predictive model research (36–40). The performance measures from the validation were discrimination with the C-statistic and calibration measured with calibration-in-the-large (CITL, ideal value of 0), calibration slope (ideal value of 1) and observed: expected ratio (E:O ratio, ideal value of 1) (33, 39).

2.7 Benchmarking survival assessment

Among the outcome evaluation and quality assurance tools are the DEF (DEFinitive outcome-based evaluation) statistical methods. These include the Z and W statistics, internationally used to compare trauma survival or mortality rates between two institutions (23, 41–43). The Z statistic, initially described by Flora in 1978 (44), compares observed survival in a group of patients with predicted survival according to the reference group (MTOS) and quantifies the difference (23). The formula is:

$$Z = \frac{S - \sum \mathrm{Pi}}{\sqrt{(\sum \mathrm{PiQi})}}$$

Where: S = observed survivors, ΣPi = is the sum of expected survival probabilities, Qi = probability of death (1-Pi), ΣPiQi = sum of the product of survival and death probabilities (23). A Z value between −1.96 and +1.96 is not statistically significant, meaning there is no evidence that the evaluated group has a survival rate significantly different from the reference with a significance level of 0.05 (23, 45). For the statistical process to be valid, Pi and Qi must be at least 5 (45). Since the *Z* value can be affected by differences in the severity of injuries between comparison groups, the M statistic measures comparability between groups. To calculate it, the survival probability is divided into 6 ranges, and the fraction of patients in each range is compared between both groups, quantifying their differences. Its formula is: M = S1 + S2 + S3 + S4 + S5 + S6, where S is the minimum value between both groups in each range. A value of M between 0.88 and 1 indicates that both groups are similar (23).

The sample size was calculated using a proportional comparison formula. *A priori*, the estimated sample size was 927 children, calculated to detect a 2% difference between observed and expected mortality.

The statistical analysis was performed using Stata version 17 (StataCorp, College Station, Texas 77845, USA).

2.8 Ethical considerations

This study was conducted in accordance with the Declaration of Helsinki and was approved by the Biomedical Research Ethics Committee of the hospital under registration number 295-2018. Given the retrospective observational nature of the study, which involved the anonymous collection of systematically gathered data, informed consent was not required, as per the decision of the ethics committee and Colombian legislation.

3 Results

A total of 1,013 children were enrolled in the study, with a complete data analysis performed after excluding 34 patients due to missing Glasgow Coma Scale information (Figure 1). The overall percentage of missing data was low (3.2%), and no imputation was conducted. Sociodemographic and clinical characteristics are summarized in Table 1 and were published in another article with a slightly larger sample that did not require the exclusion of the mentioned patients (46). The median age of participants was 12 years (IQR, 5–15 years), 73% being male. Age distribution was as follows: 21.2% were aged 0–4 years, 21.8% were aged 5–9 years, 23.9% were aged 10–14 years, and 33.1% were aged 15–17 years. Most patients (66.2%) sustained blunt trauma, while 33.8% experienced penetrating trauma. The subsidized health insurance system provided coverage for 32.9% of the patients, whereas 67.1% were insured under the contributory system, which includes private insurance. The leading causes of injury were traffic accidents (31.1%), falls (28.8%), and assaults (28.7%) (Figure 2), with firearms responsible for 97% of the violence-related deaths. Thirty-two percent of patients presented with severe trauma (ISS ≥16).

A bivariate analysis of characteristics by survival status at discharge is presented in Table 1. The median age of deceased patients was 15 years (IQR, 13–17 years), compared to 11 years (IQR, 5–15 years) in survivors ($p < 0.001$). Most deaths (83%) occurred among patients aged 10–17 years, with males representing 90% of this group. Among the deceased, 60.3% were

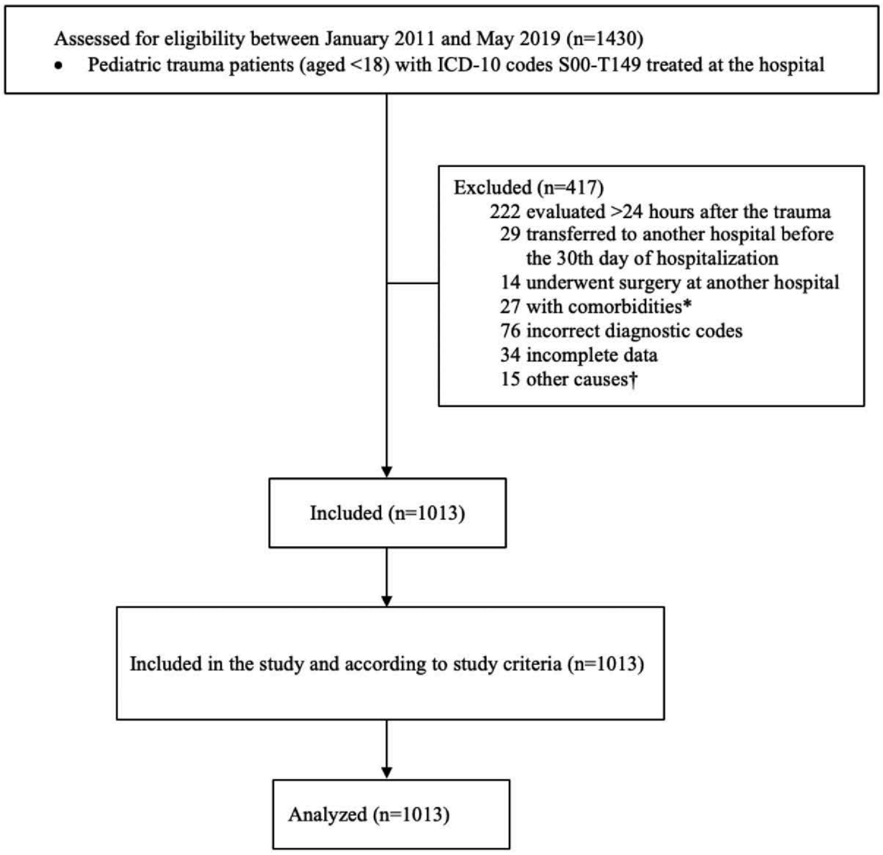

FIGURE 1
Flow chart showing the inclusion and exclusion criteria for study population. ICD-10, International classification of diseases, 10th edition. *Comorbidities: oncological, hematological, metabolic or osteoarticular comorbidities. †Other causes: unknown time since trauma, escape, transfer from provinces other than Valle del Cauca or Cauca.

covered by subsidized health insurance. Violence was the leading cause of death, followed by traffic accidents (61.3% and 33.8%, respectively). The median ISS in deceased patients was 31 (IQR, 25–37), compared to a median ISS of 9 (IQR, 4–16) in survivors. The most frequent fatal injury was traumatic brain injury (91.3%). The overall mortality rate was 5.7%, with deaths occurring at a median of 15 h post-injury (IQR, 3.8–49 h), and no deaths occurred beyond 20 days of hospitalization.

The coefficients of the Peds-TRISS are presented in Table 2. In terms of performance, a comparison between the Peds-TRISS and the original TRISS was conducted. Both demonstrated strong discrimination (Table 3). The area under the receiver-operating characteristic curve (AUROC) was 0.971 (95% CI, 0.945–0.996) for the original TRISS and 0.984 (95% CI, 0.961–0.993) for the Peds-TRISS. The DeLong test revealed no statistically significant difference in AUROCs ($p > 0.05$) (Figure 3). However, calibration was satisfactory only in the Peds-TRISS model, as indicated by the Hosmer–Lemeshow statistic (HL = 9.7, $p = 0.3$ for the Peds-TRISS and HL = 16.6, $p = 0.03$ for the original TRISS). Additionally, the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) were lower for the Peds-TRISS (AIC = 187, BIC = 197) compared to the original TRISS (AIC = 228, BIC = 238), supporting its selection based on model fit. An additional analysis of Peds-TRISS performance by age subgroup was conducted, demonstrating robust performance of the score across all age groups, as measured by discrimination and calibration (Table 4).

TABLE 1 Sociodemographic and clinical characteristics.

	Overall (n = 1,013)	Alive (n = 955)	Dead (n = 58)	p value
Median age, years (IQR)	12 (5–15)	11 (5–15)	15 (13–17)	<0.001
Age groups				<0.001
0–4 years	215 (21.2%)	209 (21.9%)	6 (10.3%)	
5–9 years	221 (21.8%)	217 (22.7%)	4 (6.9%)	
10–14 years	242 (23.9%)	230 (24.1%)	12 (20.7%)	
15–17 years	335 (33.1%)	299 (31.3%)	36 (62.1%)	
Sex, n (%)				0.062
Male	740 (73%)	691 (72.4%)	49 (84.5%)	
Female	273 (27%)	264 (27.6%)	9 (15.5%)	
Payor status, n (%)				<0.001
Private insurance	680 (67.1%)	657 (68.8%)	23 (39.7%)	
Subsidized	333 (32.9%)	298 (31.2%)	35 (60.3%)	
Origin, n (%)				0.159
Valle	752 (74%)	714 (74.8%)	38 (65.5%)	
Cauca	261 (26%)	241 (25.2%)	20 (34.5%)	
Transferred from another hospital[a]	693 (69.2%)	644 (68.2%)	49 (86%)	0.005
Mechanism of injury				<0.001
Blunt	671 (66.2%)	647 (67.7%)	24 (41.4%)	
Penetrating	342 (33.8%)	308 (32.3%)	34 (58.6%)	
Age-adjusted hypotension	72 (7%)	57 (6%)	15 (26%)	<0.001
Glasgow Coma Scale (IQR)	15 (13–15)	15 (14–15)	3 (3–6)	<0.001
ISS, median (IQR)	9 (5–17)	9 (4–16)	31 (25–37)	<0.001
RTS, median (IQR)	7.84 (7.11–7.84)	7.8 (7.5–7.8)	4 (4–5)	<0.001
TRISS, median (IQR)	0.99 (0.98–0.99)	0.99 (0.99–0.99)	0.51 (0.2–0.66)	<0.001
Peds-TRISS, median (IQR)	0.99 (0.99–0.99)	0.99 (0.99–0.99)	0.33 (0.13–0.48)	<0.001
ICU				<0.001
Yes	490 (48.4%)	443 (46.4%)	47 (81%)	
No	523 (51.6%)	512 (53.6%)	11 (19%)	
Transfusion				<0.001
Yes	251 (24.8%)	221 (23.1%)	30 (51.7%)	
No	762 (75.2%)	734 (76.9%)	28 (48.3%)	
Surgery				0.062
Yes	632 (62.4%)	603 (63.1%)	29 (50%)	
No	381 (37.6%)	352 (36.9%)	29 (50%)	
Hospital stay, hours median (IQR)	3.5 (1.7–6.9)	86.4 (43.2–168)	21.6 (4.8–50.4)	<0.001

Data are n (%) or median (IQR). IQR, interquartile range; ISS, injury severity score; RTS, revised trauma score; TRISS, trauma injury severity score; ICU, intensive care unit.
[a]Data available for 1,002 patients.

The internal validation of the Peds-TRISS demonstrated strong performance across multiple metrics, including discrimination, calibration, and model fit, as shown in Figure 4.

For the benchmarking assessment, the M statistic was 0.93, and the Z statistic was 0, indicating no statistically significant difference in survival rates between our patient cohort and the expected outcomes as defined by the comparison standard.

4 Discussion

This study assessed the performance of Peds-TRISS, an age-adjusted TRISS-based survival prediction model in a pediatric population in Colombia, using trauma center data from patients under 18 years old collected between 2011 and 2019. A significant proportion of deaths within this cohort were due to violent trauma mechanisms, and the Peds-TRISS performance was compared with that of the original TRISS. Our findings differ from the global literature, which predominantly reports trauma-related deaths due to unintentional injuries (4, 8), but align with studies conducted in Latin America (47, 48). For example, research from Brazil highlights that intentional trauma, particularly homicides, plays a significant role in adolescent mortality (49). Similarly, data from Mexico identify assaults as a major cause of trauma among adolescents, emphasizing the influence of violence on mortality patterns (50). Consistent with these findings, the SALURBAL study reports that homicides among adolescents and young adults represent a serious public health problem in Latin America, reinforcing the region's designation as one of the most violent in the world (44).

In Colombia, injuries constitute the first three causes of death from age 10, with homicide leading the list (5). This reflects a public health problem of significant magnitude, requiring substantial investment of human, financial, technical, and

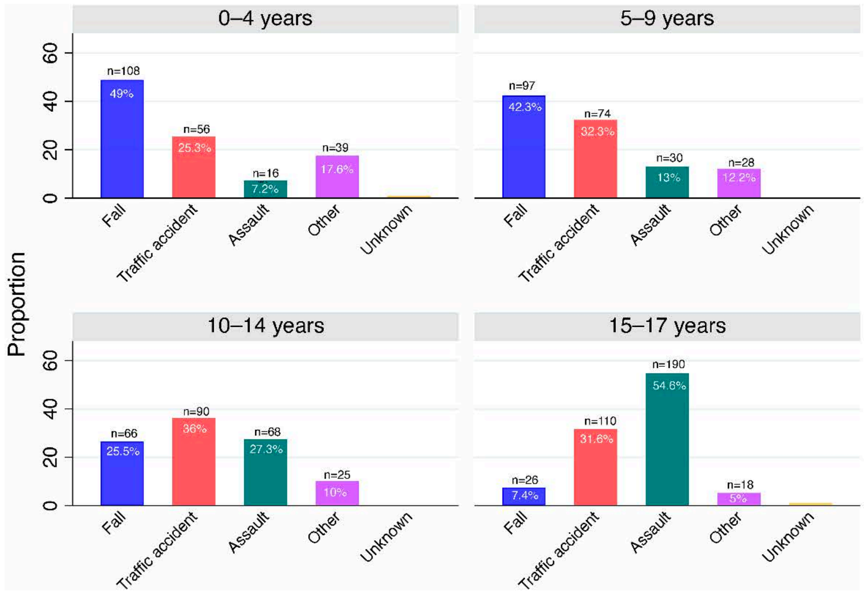

FIGURE 2
Cause of trauma by age group.

TABLE 2 Coefficients of the Peds-TRISS model derived from the study database.

	Blunt trauma		Penetrating trauma	
	Coefficient	Standard error	Coefficient	Standard error
b0	2.406	1.100	4.293	1.833
b1 (RTS)	0.744	0.161	0.811	0.134
b2 (ISS)	−0.137	0.030	−0.121	0.039
b3 (Age)	0.073	0.058	−0.190	0.096

TRISS, trauma injury severity score; RTS, revised trauma score; ISS, injury severity score.

TABLE 3 Comparative performance of TRISS models.

	AUROC (95% CI)	HL	AIC	BIC
TRISS	0.971 (0.945–0.996)	16.6 ($p = 0.03$)	228	238
Peds-TRISS	0.984 (0.961–0.993)	9.7 ($p = 0.3$)	187	197

N, 1,013; TRISS, trauma injury severity score; AUROC, area under the receiver-operating characteristic curve; CI, confidence interval; HL, Hosmer-Lemeshow; AIC, Akaike information criterion; BIC, Bayesian information criterion.

technological resources across the continuum of care—from pre-hospital services to long-term rehabilitation. Additionally, the emotional, social, and economic implications are profound, particularly due to the loss of productive years through premature death or disability (51–53). This shared regional burden underscores the need for effective interventions and predictive tools that are tailored to the specific epidemiological patterns observed in low- and middle-income countries (LMICs).

The implementation of survival prediction tools in pediatric trauma is strongly recommended by international authorities, such as the American College of Surgeons Committee on Trauma (ACS COT) in Advanced Trauma Life Support and the National Institute for Health and Care Excellence (NICE) in the United Kingdom (54, 55). These organizations recognize the utility of applying these scores for effective trauma system functioning. One of the most commonly used survival prediction tools in trauma research is TRISS, which has critical implications for patient management and trauma center quality assessment (12–16, 20) but has been less evaluated and documented in pediatric patients. TRISS incorporates anatomical and physiological variables, with the latter playing a vital role in children's adaptive response to trauma (30, 56–58). However, the parameters used (respiratory rate, systolic blood pressure) are based on findings from adult populations, limiting their reliability in pediatric settings, as these values vary significantly with age.

Our evaluation of the original TRISS model in our pediatric cohort of patients revealed limitations in its performance. Previous studies have identified similar constraints, noting

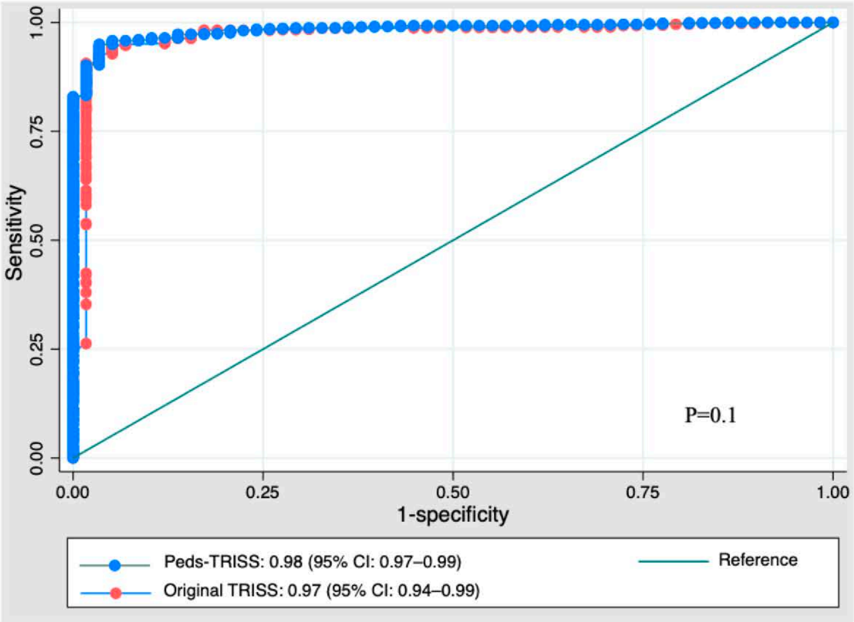

FIGURE 3
Comparative AUROC of Peds-TRISS and original TRISS. AUROC, area under the receiver-operating characteristic curve; TRISS, trauma injury severity score; CI, confidence interval.

TABLE 4 Peds-TRISS performance by age group.

	n	AUROC (95% CI)	HL (*p*)
Peds-TRISS (all ages)	1,013	0.9841 (0.9758–0.9924)	9.69 (0.3)
<5 years	215	0.9928 (0.9827–1)	1.02 (0.9981)
5–9 years	221	0.9862 (0.9670–1)	1.45 (0.9935)
10–14 years	242	0.9891 (0.9776–1)	2.01 (0.9808)
15–17 years	335	0.9690 (0.9484–0.9894)	8.33 (0.4023)

Peds-TRISS, age-adjusted trauma injury severity score; AUROC, area under the receiver-operating characteristic curve; HL, Hosmer-Lemeshow.

increased predictive power with modifications to variables like age, such as expanding age group categorizations, recalculating coefficients, or treating age as a continuous quantitative variable rather than a binary category (20, 24–26). Despite these limitations, these studies acknowledge TRISS's utility as a tool for evaluating trauma care quality improvement systems, making it the most widely used scale in injury survival studies. Additionally, a systematic review of trauma mortality prediction models underscores the importance of including demographic predictors, ideally quantitative, to enhance research quality and model performance (11).

Consistent with previous studies, we aimed to enhance the TRISS model by incorporating age as a continuous variable and recalculating all model coefficients. Our analysis revealed that the ROC curve for the Peds-TRISS model was nearly identical to that of the original TRISS, indicating that the age adjustment contributes minimally and without statistical significance to its discriminatory power. However, the adjusted model showed superior performance in terms of calibration, suggesting that the age-adjusted version aligns predicted and observed outcomes more accurately across all risk levels. This underscores the potential of tailored modifications to refine predictive models for specific populations. Furthermore, earlier studies have reported improvements in model performance following adjustments to variables such as age (20, 24, 25), highlighting the value of these modifications in enhancing predictive tools for specific clinical and epidemiological contexts.

The development and refinement of models like Peds-TRISS emphasize the importance of leveraging innovative tools to enhance trauma care, particularly in regions facing significant public health challenges. Recent advancements in artificial intelligence (AI) provide a promising avenue for further improving trauma prediction models, enabling real-time, personalized outcome predictions. By integrating large-scale data—such as imaging, vital signs, and patient history—AI-driven systems could optimize triage, refine risk stratification, and support clinical decision-making. However, for AI to achieve

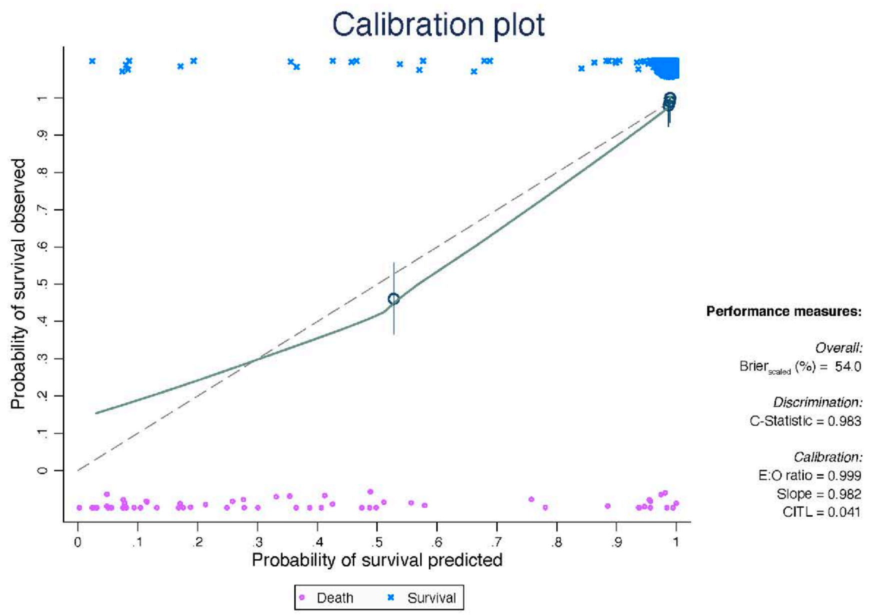

FIGURE 4
Internal validation of the peds-TRISS. E:O ratio = ratio between expected and observed events. CITL, calibration-in-the-large.

its full potential in pediatric trauma, it is crucial to adapt these technologies to the unique physiological characteristics of children and ensure access to high-quality data. Future research integrating AI into models like Peds-TRISS could facilitate more precise and actionable insights for trauma care in diverse clinical settings (59).

In addition to refining predictive models, comparative evaluation of patient outcomes provides a valuable measure of trauma center care quality (17–19). Comparative statistics enable the assessment of observed survival rates for injured patients at a trauma center against expected survival rates from national or international reference centers. The literature reports varied results (41–43); however, our findings showed no statistically significant differences between our patients and the MTOS group ($Z = 0$), with statistically valid comparability between both groups ($M = 0.93$). Integrating advancements such as AI into these frameworks could further enhance their utility, enabling real-time, personalized predictions while facilitating inter-hospital comparability.

We believe that both tools, survival prediction and outcome comparison, are valuable in clinical practice. The Trauma Audit and Research Network (TARN), the largest trauma registry in Europe, employs survival probability for prediction and comparative outcome analysis through DEF statistics (M, Z) for inter-hospital comparability (60). These tools are invaluable for objectively addressing unfavorable outcomes, facilitating the identification of contributing factors to unexpected results, and improving the quality of trauma center care. Internal validation of Peds-TRISS confirmed strong performance across all metrics (Figure 3).

Given the nature of our patients' injuries and Peds-TRISS's performance metrics, it could serve as a local reference or be applied in similar contexts, underscoring the value of developing new models based on regional data (61, 62). Moreover, its applicability extends beyond Colombia, offering potential value for regions with similar epidemiological challenges, including countries across Latin America where violence-related injuries remain a substantial burden.

The critical burden of violence-related injuries in our region, disproportionately affecting children and adolescents, underscores the urgent need for tailored solutions in trauma care. Models like Peds-TRISS offer a starting point for addressing these challenges, providing a foundation for both clinical decision-making and broader public health strategies. Healthcare professionals and researchers must actively engage in developing and disseminating evidence-based tools that identify gaps, inform interventions, and ultimately reduce the societal impact of pediatric trauma. Collaborative efforts, supported by advancements in predictive technologies and an understanding of regional epidemiological patterns, are essential to creating sustainable solutions for improving outcomes in vulnerable populations.

4.1 Limitations, strengths and future directions

This study has limitations inherent to its retrospective, single-center design, which may restrict the generalizability and transportability of the results. External validation in other pediatric cohorts is therefore essential to assess its broader applicability. Furthermore, the high proportion of deaths due to violence among adolescents may limit the model's applicability in regions with different injury epidemiology. However, it is a current and real issue in Latin America, making the model potentially useful for similar geographical and epidemiological settings. Future multicenter and prospective studies would further support the validity and applicability of Peds-TRISS.

The strengths of our study include a large pediatric cohort, the first in Latin America to adapt and apply the TRISS model in children, providing valuable information on pediatric trauma care in Latin America, where trauma registries are limited, and local data are scarce.

5 Conclusions

In conclusion, this study revealed a high rate of violence-related deaths among adolescents, highlighting a critical public health challenge. While the discriminatory power of the Peds-TRISS model was nearly identical to that of the original TRISS, its superior calibration underscores its potential to more accurately align predicted and observed outcomes across varying levels of risk. Given the characteristics of our cohort and the results obtained, the model appears promising for similar contexts in Latin America. Further validation through prospective, multicenter studies is recommended to strengthen the evidence supporting its use and to inform the development of tailored and effective pediatric trauma care interventions

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Institutional Review Board of Fundación Valle del Lili Hospital with registration number 295-2018. The studies were conducted in accordance with the local legislation and institutional requirements. The ethics committee/institutional review board waived the requirement of written informed consent for participation from the participants or the participants' legal guardians/next of kin because Given the retrospective observational nature of the study, based on the anonymous collection of systematically gathered data, informed consent was not required, as per the decision of the ethics committee and Colombian legislation.

Author contributions

AD: Writing – review & editing, Writing – original draft, Supervision, Software, Project administration, Methodology, Investigation, Formal Analysis, Data curation, Conceptualization. AG: Writing – review & editing, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Formal Analysis, Conceptualization. PG: Writing – original draft, Data curation. JA: Writing – original draft, Data curation. AF-L: Writing – review & editing, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Formal Analysis, Conceptualization.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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<u>Artículo 3:</u>

Título; Enhancing Pediatric Trauma Survival Prediction: Integrating ICISS and Glasgow Coma Scale for Greater Accuracy

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Resumen:

Background: The mortality rate from injuries globally has declined but remains high in the Americas. Despite the proven efficacy of severity scores in improving injury outcomes, their use in Latin American children has been limited. We aimed to assess the predictive performance of the International Classification of Diseases-based Injury Severity Score (ICISS) in children's survival and compare it with a novel predictive model.

Methods: A retrospective cohort study was conducted at a trauma center in Cali, Colombia, including children (<18 years) with trauma-related diagnoses from 2011 to 2019, utilizing electronic health records from the Colombian national health system. A logistic regression model was developed to predict 30-day survival. Its performance was assessed by discrimination with the area under the receiver operating characteristic curve (AUROC) and calibration and was statistically compared with a new model incorporating the Glasgow Coma Scale (GCS). The new model was internally validated by bootstrap resampling.

Results: The study included 1,047 children. The new model demonstrated superior discrimination (AUROC: 0.98, 95% CI: 0.97-0.99) compared to the ICISS-only model (AUROC: 0.94, 95% CI: 0.92-0.97), with a statistically significant difference ($p = 0.01$). Additionally, it exhibited better calibration (Hosmer-Lemeshow test: 6.7, $p = 0.6$ vs. 24.7, $p < 0.01$), indicating improved predictive accuracy. Following internal validation, the new model maintained excellent performance across all measures.

Conclusions: Combining ICISS with the GCS significantly improved the accuracy of survival prediction in children.

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ORIGINAL RESEARCH

Enhancing Pediatric Trauma Survival Prediction: Integrating ICISS and Glasgow Coma Scale for Greater Accuracy

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ABSTRACT

Background: The mortality rate from injuries globally has declined but remains high in the Americas. Despite the proven efficacy of severity scores in improving injury outcomes, their use in Latin American children has been limited. We aimed to assess the predictive performance of the International Classification of Disease-based Injury Severity Score (ICISS) in children's survival and compare it with a novel predictive model.

Methods: A retrospective cohort study was conducted at a trauma center in Cali, Colombia, including children (< 18 years) with trauma-related diagnoses from 2011 to 2019, utilizing electronic health records from the Colombian national health system. A logistic regression model was developed to predict 30-day survival. Its performance was assessed by discrimination with the area under the receiver operating characteristic curve (AUROC) and calibration and was statistically compared with a new model incorporating the Glasgow Coma Score (GCS). The new model was internally validated by bootstrap resampling.

Results: The study included 1047 children. The new model demonstrated superior discrimination (AUROC: 0.98, 95% CI: 0.97–0.99) compared to the ICISS-only model (AUROC: 0.94, 95% CI: 0.92–0.97), with a statistically significant difference ($p = 0.01$). Additionally, it exhibited better calibration (Hosmer–Lemeshow test: 6.7, $p = 0.6$ vs. 24.7, $p < 0.01$), indicating improved predictive accuracy. Following internal validation, the new model maintained excellent performance across all measures.

Conclusions: Combining ICISS with the GCS significantly improved the accuracy of survival prediction in children.

1 | Introduction

The substantial burden of morbidity and mortality resulting from injuries on the healthcare and financial systems of each country has undergone favorable changes in recent decades. However, their proportions remain significant, representing 8% of all deaths and 8% of all years lived with disability worldwide [1, 2]. Despite advancements in this regard, improvement is uneven across different regions of the world. In the Americas, deaths due to homicide predominate, and rates have not improved in the last 20–30 years [1, 3]. In the region, Colombia consistently reports homicide rates surpassing those of the Americas. In Cali, Colombia, the data are alarming with a homicide rate more than 10 times the global average (66.8 and 6.2 per 100,000, respectively) [1, 4], ranking it among the highest in the world [5]. This reflects a profound multifactorial problem that calls for a reflective analysis of our role as healthcare professionals, researchers, and members of a violent society, requiring prioritized interventions [6]. Being aware that preventing such deaths would be the ideal scenario [7], our efforts as healthcare workers and researchers must also be directed toward improving the outcome of injured patients. In this regard, the use of scores that predict survival has been shown to positively impact patient outcomes [8–10], recommending their use as part of trauma care quality improvement programs [11, 12]. The International Classification of Diseases, 10th Revision (ICD-10)-based Injury Severity Score (ICISS) [13] predicts survival based on the international diagnostic coding of diseases, which is included in many administrative databases, facilitating its calculation, and resulting in considerable resource savings. Furthermore, it has shown reliable results with its application [14–16], making it a tool worth considering. To date, the performance of ICISS has not been evaluated in Latin American children.

Given Colombia's mandatory electronic recording system for all patients, including their ICD-10 diagnoses [17], we aimed to assess the performance of ICISS in injured children treated at our hospital. Additionally, considering the prevalence of traumatic brain injury as a leading cause of death in children [18] and the significance of physiological response to trauma in this age group [19], following recommendations from predictive mortality models in trauma studies advocating for the incorporation of physiological variables into predictive models [20], we aimed to compare the performance of ICISS with a new predictive model that combines ICISS and the variable Glasgow Coma Scale (GCS).

2 | Methods

2.1 | Study Design and Participants

This study provides a retrospective analysis utilizing robust statistical models at a leading trauma center in Colombia. It included patients under 18 years of age who received emergency care for injuries resulting from external causes. Children with chronic conditions that could influence clinical management or affect outcomes were excluded from the analysis. Additionally, cases involving drowning, thermal injuries, or toxic exposures were excluded.

This study represents a secondary analysis of a previously published dataset [21]. We acknowledge that while the dataset has been previously analyzed and reported, this study introduces a novel approach by incorporating the GCS into the predictive model.

2.2 | Study Setting

This study involved a cohort of pediatric patients who received emergency care at the Fundación Valle del Lili University Hospital in Cali, Colombia, from January 2011 to May 2019. The hospital provides care for severe trauma and other high-complexity pathologies. Colombia is in the north-west of South America, and Cali, with 2.5 million inhabitants, is one of its major cities [22, 23]. Fundación Valle del Lili University Hospital has 721 beds, 229 as intensive care unit (ICU) beds, 40 in a pediatric ICU, and 10 in a trauma ICU. It has around 8000 trauma consultations each year, 700 of them requiring the highest level of trauma team activation.

The study was conducted in accordance with the principles of the Declaration of Helsinki and obtained ethical approval from the hospital's Biomedical Research Ethics Committee (Registration No. 295-2018). Due to the retrospective and observational nature of the study, which utilized anonymized, systematically collected data, the ethics committee, following Colombian regulations, waived the need for informed consent.

2.3 | Data Sources and Measurement

Patient selection was conducted using the Individual Health Services Performance Registry (Registro Individual de Prestación de Servicios de Salud, RIPS) [17], which contains the study's inclusion criteria. Medical records were subsequently reviewed to verify diagnostic coding. Sociodemographic variables were obtained from RIPS, whereas clinical variables, injury characteristics, and severity measures were extracted from medical records.

The main outcome measured was mortality occurring within 30 days of admission. The ICISS variable was calculated as described below, and a logistic regression model was constructed to predict the outcome (alive/dead at discharge). The first model included ICISS as the independent variable, whereas the second model incorporated both ICISS and GCS. The two models were then statistically compared.

2.4 | International Classification of Diseases, 10th Revision (ICD-10)-Based Injury Severity Score (ICISS)

A score that evaluates the anatomical component of injuries. First, the diagnosis-specific survival probability (DSPs) of each injury coded in the ICD-10 is calculated, and then the ICISS is estimated, which is the survival probability for each patient based on the product of their DSPs (previously termed survival risk ratio) [13, 24]. Its formula is

$$\text{DSPs} = \frac{\text{Number of survivors with an ICD-10 diagnosis}}{\text{Number of patients with an ICD-10 diagnosis}}$$

$$\text{ICISS} = \text{DSPs}_{\text{inj1}} \times \text{DSPs}_{\text{inj2}} \times \cdots \text{DSPs}_{\text{inj last}},$$

where $DSPs_{inj1}$, $DSPs_{inj2}$, and $DSPs_{inj\ last}$ represent the probability of survival of Injury 1, Injury 2, and the last injury, respectively. The result ranges from 0 to 1 and was calculated for all patients included in the study.

2.5 | Personal Health Records System (Registro Individual de Prestación de Servicios, RIPS)

This is a systematic record of information from Colombia's General System of Social Security in Health (Sistema General de Seguridad Social en Salud, SGSSS), covering all health services provided to all patients. It collects sociodemographic information, ICD-10 diagnoses, required procedures and care, destination and vital status at discharge, and cause of death if applicable, as it is mandatory for each patient [17].

2.6 | Statistical Analysis

Categorical variables were expressed as frequencies and percentages and compared between the living and deceased groups using the chi-squared test. Continuous variables were presented as median and interquartile range (IQR) and compared using the Wilcoxon–Mann–Whitney test.

A logistic regression model was constructed, with ICISS serving as the independent variable and survival status at the time of discharge as the dependent variable. Model performance was analyzed by evaluating discrimination through the area under the receiver operating characteristic (AUROC) curve and assessing calibration using the Hosmer–Lemeshow goodness-of-fit test [25]. A second logistic regression model was created, incorporating both ICISS and GCS as continuous predictor variables. To ensure robustness, internal validation was performed using the bootstrap method, which provides stable, less biased estimates and is recognized as a robust internal validation technique in predictive modeling research [26–30].

The performance of the two models (ICISS-only vs. ICISS + GCS) was evaluated through the Akaike information criterion (AIC) [31] and the Bayesian information criterion (BIC) [32]. A graphical comparison of model discrimination was conducted, and statistical significance was assessed.

This study follows the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines. Statistical analyses were performed using Stata version 17 (StataCorp, College Station, Texas, USA).

3 | Results

The eligible cohort comprised 1047 children (median age: 12 years; IQR: 5–15), with a predominance of males (73.7%). Severe trauma (ISS $\geq$ 16) was identified in 31% of patients, and the median ICISS was 0.82. The overall mortality rate was 5.9% ($n = 62$), with traumatic brain injury (TBI) emerging as the primary cause of death (85.5%). Notably, injuries involving firearms accounted for 58% of all fatalities. Deceased patients exhibited significantly lower GCS scores (median: 3) and ICISS values (median: 0.2) compared to survivors, whose corresponding values were 15 and 0.8, respectively.

To assess predictive performance, we evaluated a model incorporating both GCS and ICISS, demonstrating superior discrimination compared to an ICISS-only model (AUROC: 0.98, 95% CI: 0.97–0.99 vs. AUROC: 0.94, 95% CI: 0.92–0.97). The difference between the two models was statistically significant ($p = 0.01$) (Figure 1). In terms of calibration, the ICISS-only model showed suboptimal performance, whereas the new model achieved good calibration (Hosmer–Lemeshow test: 24.7, $p < 0.01$ vs. 6.7, $p = 0.6$) (Table 1). Additionally, model fit indicators favored the combined GCS-ICISS model, as reflected by lower Akaike information criterion (AIC) and Bayesian information criterion (BIC) values compared to the ICISS-only model (Table 1). These results support the adoption of the combined model for prognostic assessment.

Internal validation confirmed the robustness of the new predictive model across all performance metrics, demonstrating excellent discrimination and calibration (Figure 2).

4 | Discussion

This study presents the findings from a cohort of pediatric patients treated for injuries at a high-complexity trauma center in Colombia. The primary victims were males aged 10–17, predominantly from lower socioeconomic backgrounds. The high incidence of violent injuries, particularly firearm-related trauma, highlights an urgent public health challenge in this population. Unlike previous studies where unintentional injuries predominated [33, 34], our findings align with World Health Organization's statistics, which indicate that homicide rates in the Americas surpass the global average, and with reports from the United Nations Office on Drugs and Crime data, documenting a rise in homicides among children under 14 [3]. Although socioeconomic disparities increase the risk of violence, this is a complex issue shaped by educational, cultural, political, and judicial factors. Addressing this challenge is essential, as it starkly contrasts with the Sustainable Development Goals' vision of a world free from violent deaths by 2030 [3, 35].

Among the strategies proven to improve survival in injured children are trauma scoring systems, which help prioritize and optimize patient care while enhancing overall treatment quality. One such system is the ICISS, which predicts survival based on diagnoses from the International Classification of Diseases [13, 36], which is particularly advantageous due to its ability to utilize routinely recorded in administrative databases, minimizing additional resource requirements. Since its development, ICISS has been validated in diverse contexts with promising results [14–16]. The International Collaborative Effort on Injury Statistics (ICE), co-hosted with the World Health Organization in the biennial World Conference on Injury Prevention and Safety Promotion [37], supports the use of DSPs as a research tool to facilitate the collection, analysis, and international comparability of injury data. Given the ease of application of

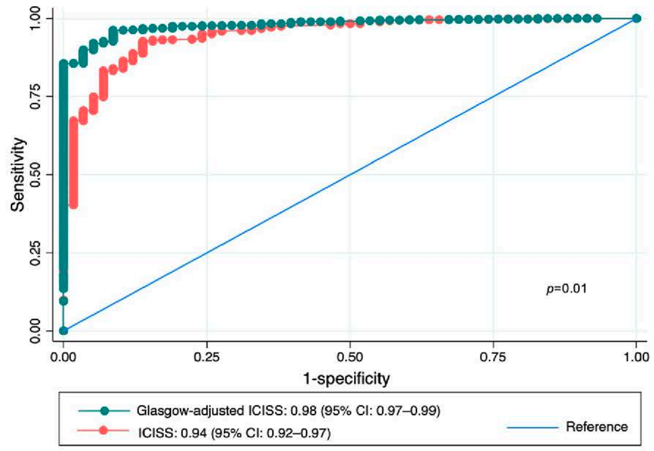

FIGURE 1 | Comparative ROC curves of ICISS and Glasgow-adjusted ICISS models. ICISS = ICD10-derived injury severity score, ROC = receiver-operating characteristic.

TABLE 1 | Survival prediction: Comparative performance of ICISS and Glasgow-adjusted ICISS models.

	OR; *p* value (95% CI)	AUROC	HL (Prob > χ^2)	AIC	BIC
ICISS	1.11; $p < 0.01$ (1.08–1.13)	0.94	24.7 (< 0.01)	246	256
Glasgow-adjusted ICISS	1.6; $p < 0.01$ (1.38–1.85)	0.98	6.7 (0.6)	181	196

Note: n = 1047.
Abbreviations: AIC = Akaike information criterion, AUROC = area under the receiver-operating characteristic curve, BIC = Bayesian information criterion, CI = confidence interval, HL = Hosmer–Lemeshow, ICISS = ICD10-derived Injury Severity Score, OR = odds ratio.

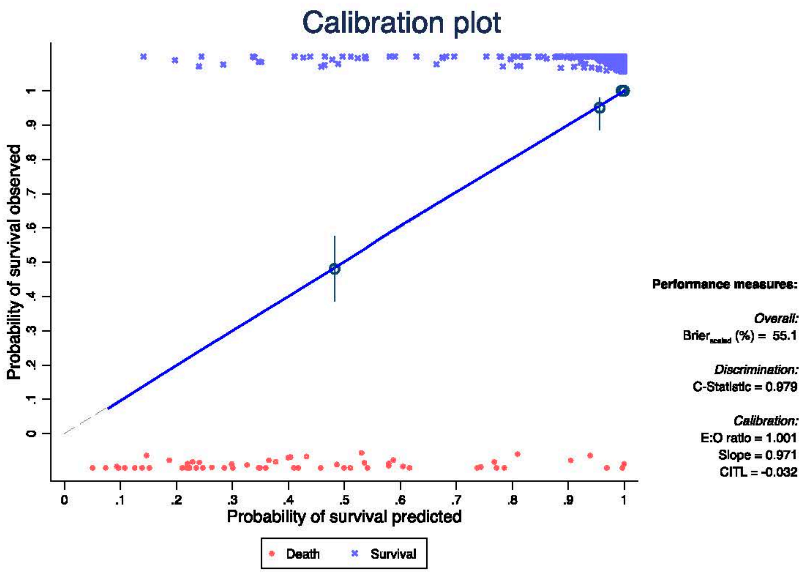

FIGURE 2 | Internal validation of the Glasgow-adjusted ICISS. CITL = calibration-in-the-large, E:O ratio = ratio between expected and observed events.

ICISS, we aimed to evaluate its performance in our setting, as it had not been previously assessed in pediatric populations within our country.

Our findings demonstrate a good AUROC value for ICISS; however, it did not exhibit good calibration, indicating a poor fit between observed and expected survival probabilities. This finding is common in studies evaluating predictive models [16, 24, 38]. Given the limitations of ICISS as a standalone predictor, to enhance prognostic accuracy, we incorporated additional variables. Considering that head trauma represents the primary cause of mortality related to trauma in the pediatric and recognizing that children exhibit distinct physiological responses to traumatic injuries [39], we developed a new predictive model integrating GCS as a continuous quantitative physiological variable alongside ICISS. GCS is a widely used predictor [24], and previous research suggests that incorporating physiological variables in a continuous manner enhances model performance [24, 25, 40, 41].

The comparison of AUROC values demonstrated that the new model significantly outperformed ICISS alone ($p = 0.01$). Additionally, the new model exhibited superior calibration, and its internal validation confirmed excellent discrimination and calibration metrics. Following the principle of model parsimony, which favors simplicity while maintaining predictive power [29], we believe that integrating ICISS and GCS is a promising approach in our context.

This study builds upon a previously reported dataset [21] but employs a novel analytical approach by integrating ICISS and GCS to improve survival prediction. Unlike the previous analysis, which evaluated a pediatric trauma score, this study develops a new combined predictive model that incorporates variables systematically recorded in administrative databases, leading to significant savings in human and technological resources. Additionally, the model underwent internal validation and provides a comparative evaluation against the unadjusted score. These distinctions highlight the contribution of this research to the advancement of prognostic tools for pediatric trauma care.

4.1 | Strengths and Limitations

One of the strengths of this study is the substantial sample size, which enhances statistical power, a well-defined cohort, robust statistical analysis, and internal validation via bootstrapping. Additionally, we evaluated an easily applicable score within our national context, leveraging systematically recorded data in administrative databases and clinical records, such as ICD-10 diagnoses and GCS. The parsimonious construction of our predictive model based on these two variables further reinforces its utility.

However, limitations must be considered. The retrospective design may introduce selection bias. Additionally, as the study was conducted at a single center, its generalizability may be limited. Although coding errors in diagnostic classifications represent a potential limitation, previous research suggests that although such errors are common, they generally do not significantly impact severity estimation or mortality prediction [42]. Another limitation is the absence of prehospital mortality data. Given that most trauma-related deaths occur in the prehospital setting [43, 44], incorporating this data could further refine ICISS performance [41]. Moreover, we observed a significant proportion of adolescent deaths due to interpersonal violence, which limits the transportability of our findings. Nevertheless, we believe reporting this data is essential, as recognizing gaps is the first step toward developing targeted intervention strategies. Additionally, although mortality was the primary outcome measure, future studies should consider long-term functional outcomes and external validation to assess the generalizability of these findings.

5 | Conclusions

Integrating neurological assessment into trauma severity scores enhances prognostic accuracy and may influence triage decisions and resource allocation in emergency care settings. Given the systematic collection of these variables, this approach is resource-efficient. Future research should investigate its applicability across diverse pediatric populations to support the development of evidence-based strategies aimed at improving injury survival outcomes while reducing long-term disability.

Author Contributions

A. De los Ríos-Perez: conceptualization, data curation, formal analysis, investigation, methodology, project administration, resources, software, supervision, validation, writing – original draft, writing – review and editing. **A. García Marín:** conceptualization, data curation, formal analysis, investigation, methodology, project administration, resources, supervision, validation, writing – review and editing. **A. Giraldo Arboleda:** data curation, investigation, writing – original draft. **A. Fandiño-Losada:** conceptualization, data curation, formal analysis, investigation, methodology, project administration, resources, supervision, validation, writing – review and editing.

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Ethics Statement

The study adhered to the principles outlined in the Declaration of Helsinki and received ethical approval from the Biomedical Research Ethics Committee of the hospital with the registration number 295-2018. Given the retrospective and observational design of the research, which involved the anonymous use of systematically collected data, the ethics committee, in accordance with Colombian regulations, waived the requirement for informed consent.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

In accordance with the Declaration of Helsinki, the datasets generated and analyzed in this study are not publicly accessible. However, they can be obtained from the corresponding author upon a reasonable request.

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5. DISCUSION

5.1 Discusión general de los estudios

Este estudio presenta datos sobre la frecuencia, severidad y características de los traumatismos en una muestra pediátrica de Colombia. Los accidentes de tránsito y las agresiones fueron las causas más frecuentes de las lesiones. Los resultados sobre los accidentes de tránsito concuerdan con los reportados por otros investigadores a nivel mundial (71-75) y en la región (76,77). Estas lesiones son potencialmente prevenibles mediante la implementación y optimización de medidas de prevención adecuadas y exhaustivas, vinculadas a un sistema de vigilancia sólido y robusto. Cabe destacar que, en cuanto a las muertes reportadas en nuestro estudio, éstas fueron de carácter intencional predominantemente, causadas por armas de fuego, lo que contrasta con la mayoría de los estudios publicados que informan que las muertes por trauma son de carácter no intencional (6,9), pero coincide con varios reportes en América Latina (1,78). Por ejemplo, una investigación de Brasil destaca que el trauma intencional, en particular el homicidio, desempeña un papel significativo en la mortalidad de adolescentes (79). En consonancia con estos hallazgos, el estudio SALURBAL informa que los homicidios entre adolescentes y adultos jóvenes representan un grave problema de salud pública en América Latina, lo que refuerza la clasificación de la región como una de las más violentas del mundo (80,81).

También observamos que la mayoría de los niños fallecidos presentaron trauma craneoencefálico severo y que la muerte se produjo rápidamente tras ocurrida la lesión, similar a lo encontrado por otros estudios que analizaron la mortalidad por trauma (82). La proporción de fallecidos que no fueron sometidos a cirugía ni fueron trasladados a Cuidado Intensivo se atribuyó a la extrema severidad al ingreso, con una rápida progresión a muerte encefálica y muerte. La gran proporción de pacientes hospitalizados que fueron transferidos desde hospitales de menor complejidad, principalmente aquellos que fallecieron, es un hallazgo destacable de nuestro estudio pues si bien no disponemos de información sobre la atención recibida en los hospitales de origen, llegaron en condición de extrema gravedad dada por estado de coma, hipotensión, que en niños se considera una situación terminal (83) o puntuaciones medianas de PTS e ISS de 0 y 31, respectivamente (33,84). Estos pacientes críticos deben ser trasladados directamente desde el lugar de la lesión a un centro de trauma, ya que el riesgo de muerte es alto e inminente sin una atención adecuada y una intervención oportuna (32,84,85).

Aunque la mortalidad por lesiones ha disminuido a nivel mundial, las lesiones siguen siendo una de las principales causas de muerte (9), y se siguen perdiendo muchas vidas jóvenes. En Colombia, las lesiones constituyen las tres primeras causas de muerte a partir de los 10 años, con el homicidio encabezando la lista (86). Si bien las disparidades socioeconómicas aumentan el riesgo de violencia, se trata de un problema complejo, condicionado por factores educativos, culturales, políticos y judiciales. Abordar este desafío es esencial, ya que contrasta marcadamente con la visión de los Objetivos de Desarrollo Sostenible de un mundo libre de muertes violentas para 2030 (14,87).

Estas muertes solo representan la punta del iceberg, ya que son más los niños que sobreviven, pero requieren atención hospitalaria o quedan con algún grado de discapacidad (75,88). Esto refleja un problema de salud pública de magnitud significativa, con implicaciones emocionales, sociales y económicas profundas, en particular debido a la pérdida de años productivos por muerte prematura o discapacidad (89,90), que, si bien requiere una inversión de recursos, ofrece beneficios sanitarios y económicos más inmediatos que el control de enfermedades crónicas (91).

La gran carga regional generada por las lesiones subraya la necesidad de intervenciones eficaces adaptadas a los patrones epidemiológicos específicos observados en los países y debe abordarse con inversión y esfuerzos conjuntos a nivel local, internacional e intersectorial (91,92). Entre estas iniciativas se incluyen las propuestas por la Organización Mundial de la Salud (OMS), en colaboración con los Centers for Disease Control and Prevention de los Estados Unidos (CDC), la Organización Panamericana de la Salud (OPS) y el Fondo de las Naciones Unidas para la Infancia (UNICEF), entre otras organizaciones, como la implementación de las estrategias INSPIRE para la prevención de la violencia contra los niños (93).

Aunque la prevención de lesiones constituye el enfoque ideal en salud pública (94), en la práctica estas siguen ocurriendo a pesar de los esfuerzos más rigurosos. En este sentido, los profesionales de la salud debemos estar preparados para ofrecer una atención adecuada, basada en herramientas que optimicen la toma de decisiones clínicas. Entre ellas, el uso de escalas de clasificación ha demostrado contribuir positivamente al pronóstico de los pacientes (23,95,96), por lo que su implementación forma parte fundamental de un abordaje integral en escenarios de trauma (97).

Nosotros evaluamos tres escalas, entre las cuales, la PTS fue la única que mostró buenos resultados de desempeño en todas las métricas evaluadas, sin necesidad de hacer ajustes a sus componentes, por lo que, siguiendo las recomendaciones del American College of Surgeons Committee on Trauma (17), y considerando su fácil aplicación, respaldamos y promovemos su uso en nuestro contexto (Colombia y Latinoamérica). Las otras dos escalas mostraron resultados menos favorables en su versión original, lo que nos llevó a desarrollar nuevos modelos predictivos, haciendo ajustes a sus componentes o al modelo predictivo, encontrando excelentes resultados dados por una mayor precisión pronóstica.

Cada una de las tres escalas tiene sus ventajas, por lo que el criterio de selección probablemente deba basarse en el escenario clínico en que nos encontremos — ya sea extrahospitalario o intrahospitalario — y en los recursos disponibles, pues en el caso de la PTS, una de sus grandes utilidades es que puede ser fácilmente aplicada por personal técnico en un ámbito extrahospitalario y permite trasladar adecuadamente el niño lesionado desde la escena del trauma, sin incurrir en un sobreuso de hospitales de alta complejidad para la atención de traumas triviales, ni retrasar la atención de niños graves en centros con recursos insuficientes para su atención. Por el contrario, la Peds-TRISS, tiene un mayor grado de complejidad para su cálculo lo que le confiere mayor utilidad en un ámbito intrahospitalario, pero tiene aplicaciones adicionales como hacer evaluaciones comparativas de resultados interinstitucionales, como parte de los programas de mejora de calidad de atención, y es la más utilizada por investigadores de supervivencia en trauma. Por último, la ICISS ajustada por ECG, tiene la gran ventaja de poder ser utilizada a partir de bases de datos administrativas facilitando su uso sin necesitar recursos adicionales a los utilizados sistemáticamente en la atención de pacientes lesionados.

De esa forma y con los resultados encontrados, disminuimos la brecha existente en el conocimiento procedente de nuestra región y nos alineamos con los Objetivos de Desarrollo Sostenible de un mundo libre de muertes violentas para 2030 (98), dado que la investigación permite la formulación e implementación objetivas de estrategias que contribuyen tanto a la prevención como a la mejora del pronóstico de los pacientes (99).

5.2 Discusión especifica derivada de cada uno de los artículos publicados

Performance of the Paediatric Trauma Score on survival prediction of injured children at a major trauma centre: A retrospective Colombian cohort, 2011−2019

Este artículo forma parte del compendio de publicaciones. El objetivo fue evaluar el desempeño del PTS en una población cuyas características difieren de aquellas en las que la escala fue originalmente desarrollada. Quisimos evaluar esta escala porque fue diseñada específicamente para su aplicación en niños (26), es ampliamente utilizada en el ámbito internacional, y consistentemente recomendada por el ATLS (17), referente mundial en la atención del trauma, sin embargo, no utilizada rutinariamente en la atención de niños lesionados en nuestro país.

Hasta la realización de esta tesis, su desempeño no había sido evaluado en América Latina. Encontramos un excelente rendimiento de la escala en nuestro estudio, tanto en discriminación como en calibración, lo cual también ha sido demostrado por investigadores de otros países (71,100-105). Otros estudios, como el de Yoon et al. (106), informaron que, si bien el rendimiento del PTS fue bueno, fue inferior al de otras puntuaciones como la puntuación BIG (compuesta por el déficit de base [B], la razón internacional normalizada INR [I] y la ECG [G]). Sin embargo, estas puntuaciones requieren pruebas de laboratorio, lo que implica un tiempo adicional de espera para los resultados o un cálculo complejo en algunos contextos. Además, puede no estar disponible en todos los niveles de atención ni en el ámbito extrahospitalario.

Pese a las diferencias poblacionales, lesionales, locativas y sanitarias, existen varias razones para explicar el buen rendimiento de la PTS en nuestro estudio. En primer lugar, la PTS combina factores anatómicos y fisiológicos, incluido el peso, entre sus variables, reconociendo que la severidad de las lesiones y las respuestas fisiológicas difieren según la edad o el tamaño corporal (22,107). En segundo lugar, la PTS evalúa el sistema nervioso central, lo cual es de gran relevancia en niños, no solo por la mayor frecuencia de trauma craneoencefálico en niños, sino porque la afectación multisistémica, también frecuente en este grupo etario y en los traumatismos severos, el nivel de consciencia es uno de los principales signos de hipoperfusión e inestabilidad hemodinámica que se produce incluso antes de la hipotensión. Esto va en consonancia con las recomendaciones de investigadores que sugieren la combinación de variables anatómicas y fisiológicas y la inclusión de variables demográficas (como la edad) de forma cuantitativa continua, para mejorar la calidad y el desempeño de modelos de predicción de supervivencia en trauma (18).

Su uso tiene otras ventajas además de su buena capacidad predictiva de supervivencia, y estas son, la facilidad de cálculo, tanto en entornos prehospitalarios como hospitalarios, por parte de personal sanitario, tanto médico como no médico; la cuantificación de la severidad del trauma, que apoya la asignación y el uso eficiente de recursos para la atención de niños con lesiones, la difusión de datos y experiencias en los hospitales, y la generación de evidencia científica que facilita la toma objetiva de decisiones en salud pública. También tiene utilidad como elemento de control de calidad, pues permite identificar fallecimientos con lesiones menos severas, en los que podrían haberse producido errores de manejo. Sin embargo, este articulo no abordó las características del tratamiento recibido, ya que no formaba parte de los objetivos establecidos.

Por todo lo anterior, y los buenos resultados encontrados, es razonable incluir sistemáticamente el uso del PTS en la atención de niños con lesiones. Con su uso, como profesionales de la salud de nuestro país, podríamos contribuir y alinearnos con la Estrategia Mundial para la Salud de la Mujer, el Niño y el Adolescente, que busca, entre otros objetivos, reducir la mortalidad prevenible y mejorar la salud de los niños y adolescentes para 2030 (98).

Quality of pediatric trauma care: development of an age-adjusted TRISS model and survival benchmarking in a major trauma center

En este artículo evaluamos el desempeño del TRISS, desarrollamos un nuevo modelo predictivo, Peds-TRISS, basado en el TRISS, pero con ajustes en sus variables para que la edad sea considerada en niños, y se comparó el desempeño de ambos modelos. El TRISS es una de las herramientas de predicción de supervivencia más utilizadas en la investigación en trauma, con importantes implicaciones tanto para el manejo de los pacientes como para la evaluación de la calidad de la atención en centros de trauma (30,108-112). Sin embargo, ha sido menos evaluado en poblaciones pediátricas y en contextos latinoamericanos.

El TRISS incorpora variables anatómicas y fisiológicas lo que le confiere un potencial valor a su aplicación en niños, considerando que los parámetros fisiológicos tienen un papel fundamental en la respuesta adaptativa del niño al trauma (17,29,107,113). Sin embargo, los valores utilizados para calcular los coeficientes (frecuencia respiratoria, presión arterial sistólica) corresponden a los de adultos, lo que limita su fiabilidad pues estos valores varían significativamente con la edad.

La evaluación del TRISS original en nuestra cohorte pediátrica reveló limitaciones en su rendimiento. Estudios previos han identificado limitaciones similares, logrando aumentar el poder predictivo de diferentes formas, recalculando sus coeficientes o modificando variables como la edad categorizándola por grupos etarios o tratándola como una variable cuantitativa continua en lugar de una cualitativa binaria (30,114-116). A pesar de estas limitaciones, estos estudios reconocen la utilidad de TRISS como herramienta predictiva y para evaluar la calidad de la atención traumatológica, convirtiéndola en la escala más utilizada en estudios de supervivencia a lesiones de causa externa.

Una revisión sistemática reciente de modelos predictivos de mortalidad por trauma resalta la importancia de incluir predictores demográficos cuantitativos, para mejorar la calidad de la investigación y el rendimiento de los modelos de predicción (18).

En consonancia con estudios previos, nuestro objetivo fue mejorar el desempeño del TRISS tratando la edad como una variable continua y recalculando todos los coeficientes del modelo, dando lugar a un TRISS modificado: Peds-TRISS. El análisis comparativo del desempeño de ambos modelos, TRISS y Peds-TRISS, se realizó con varias técnicas estadísticas: discriminación, calibración, AIC y BIC. Aunque la discriminación no mostró una diferencia estadísticamente significativa en el AUROC entre ambos modelos, si se observó un rendimiento superior de Peds-TRISS en términos de calibración, indicando una mayor precisión entre resultados previstos y observados en todos los deciles de riesgo. La aplicación de AIC y BIC como criterios para la evaluación y comparación estadística de los 2 modelos predictivos, fue favorable para la selección de Peds- TRISS como mejor modelo. Dado que, como se mencionó antes, estudios anteriores han reportado mejoras en el rendimiento del modelo tras ajustar variables como la edad (30,114,116), nuestros hallazgos subrayan el potencial de las modificaciones personalizadas para ajustar los modelos predictivos en poblaciones y contextos clínicos y epidemiológicos específicos. El desarrollo y perfeccionamiento de modelos como Peds-TRISS enfatiza la importancia de aprovechar herramientas innovadoras para mejorar la atención traumatológica, especialmente en regiones que enfrentan importantes desafíos de salud pública.

Por otra parte, la evaluación comparativa de los resultados entre centros proporciona una valiosa medida de la calidad de atención (42-44).
Las estadísticas comparativas permiten evaluar las tasas de supervivencia observadas de los pacientes lesionados en un centro de trauma frente a las esperadas en centros de referencia nacionales o internacionales. La literatura presenta resultados variados en este sentido (64-66); nosotros destacamos los nuestros, que fueron favorables, partiendo de una comparabilidad estadísticamente válida entre nuestros pacientes y los del grupo MTOS, considerando éste como grupo de referencia. La Trauma Audit and Research Network (TARN), el mayor registro de trauma de Europa utiliza la probabilidad de supervivencia como medida de predicción y el análisis comparativo de resultados mediante los estadísticos DEF (Z y W) para la comparabilidad interhospitalaria (117), los cuales utilizamos en nuestro estudio.

Ambas herramientas, la predicción de supervivencia y la evaluación comparativa de resultados, constituyen un elemento invaluable en la práctica clínica que permite un enfoque objetivo de los resultados desfavorables, profundizando en la identificación de factores que contribuyen a un resultado inesperado y, por lo tanto, llevando a mejorar la calidad de atención en un centro de trauma.

La validación interna de Peds-TRISS confirmó un excelente rendimiento en todas las métricas evaluadas. Dada la naturaleza de las lesiones de nuestros pacientes y los resultados de desempeño de Peds-TRISS, este modelo podría servir como referencia local o aplicarse en contextos similares, lo que apoya el valor de desarrollar nuevos modelos basados en datos regionales (118,119). Además, su aplicabilidad se extiende más allá de Colombia, ofreciendo un valor potencial para regiones con desafíos epidemiológicos similares, incluyendo países de América Latina donde las lesiones relacionadas con la violencia siguen representando una carga considerable.

La crítica carga de lesiones relacionadas con la violencia en nuestra región, que afecta desproporcionadamente a niños y adolescentes, suscita la urgente necesidad de soluciones personalizadas para la atención del trauma. Modelos como Peds-TRISS ofrecen un punto de partida para abordar estos desafíos, sentando las bases para la toma de decisiones clínicas y la implementación de estrategias más amplias de salud pública. Los profesionales de la salud y los investigadores debemos participar activamente en el desarrollo y la difusión de herramientas basadas en la evidencia que identifiquen las brechas y conduzcan a reducir el impacto multidimensional del trauma pediátrico. Los esfuerzos colaborativos, respaldados por la comprensión de los patrones epidemiológicos regionales y los avances en herramientas predictivas, son esenciales para crear soluciones sostenibles que mejoren los resultados en poblaciones vulnerables.

Enhancing Pediatric Trauma Survival Prediction: Integrating ICISS and Glasgow Coma Scale for Greater Accuracy

En este artículo se evaluó el desempeño del ICISS en la población de estudio. Su capacidad para predecir la supervivencia a partir de los diagnósticos codificados según la CIE-10 (27,120) representa una ventaja significativa, ya que, al basarse en datos registrados de forma sistemática, permite su cálculo a partir de bases de datos administrativas, implicando un ahorro significativo en recursos humanos y tecnológicos.

Desde su desarrollo, el ICISS se ha validado en diversos contextos con resultados prometedores (121-124). El Esfuerzo Colaborativo Internacional sobre Estadísticas de Lesiones (ICE), organizado conjuntamente con la Organización Mundial de la Salud en la Conferencia Mundial sobre Prevención de Lesiones y Promoción de la Seguridad, que se celebra cada dos años (5), apoya el uso de las DSP como herramienta de investigación para facilitar la recopilación, el análisis y la comparabilidad internacional de los datos sobre lesiones. Dada la facilidad de aplicación, quisimos evaluar el rendimiento del ICISS, pues no se había evaluado previamente en poblaciones pediátricas de nuestro país. Nuestros hallazgos demuestran una buena discriminación demostrada con un valor alto del AUROC; sin embargo, no mostró una buena calibración, lo que indica un ajuste deficiente entre las probabilidades de supervivencia observadas y esperadas. Este hallazgo es común en estudios que evalúan modelos predictivos (34,123,125). Dados los resultados encontrados con ICISS como predictor independiente, nos propusimos incorporar otras variables para mejorar la precisión pronóstica. Considerando que el trauma craneoencefálico representa la principal causa de mortalidad relacionada con trauma en niños y reconociendo que los niños presentan respuestas fisiológicas distintas a las lesiones traumáticas (107), desarrollamos un nuevo modelo predictivo que integra la ECG como una variable fisiológica cuantitativa continua junto con la ICISS. La ECG es un predictor ampliamente utilizado (34), y estudios previos sugieren que la incorporación de variables fisiológicas, de carácter cuantitativo continuo, mejora el rendimiento de modelos predictivos (34,55,126,127). La comparación de ambas escalas, ICISS e ICISS ajustada por ECG, demostró buenos resultados a favor de la última. El valor de AUROC del nuevo modelo superó significativamente el del ICISS original ($p = 0{,}01$) y también presentó una mejor calibración. La validación interna del nuevo modelo confirmó excelentes resultados en todas las métricas evaluadas.

Siguiendo el principio de “modelo parsimonioso”, que prioriza la simplicidad manteniendo la capacidad predictiva (61), creemos que la integración de ICISS y GCS es un enfoque prometedor en nuestro contexto.

5.3 Fortalezas

Una de las principales fortalezas de este trabajo fue el tamaño de la muestra, que constituye una de las cohortes más grandes de niños lesionados reportadas en América Latina. Esto no solo mejora la potencia estadística de los análisis realizados, sino que también aporta información valiosa sobre el trauma pediátrico en una región donde los registros son limitados, pero esenciales para implementar estrategias de intervención efectivas que impacten positivamente en los desenlaces clínicos.

El uso del registro del Sistema General de Seguridad Social en Salud (SGSSS) de Colombia permitió obtener gran parte de las variables necesarias para el estudio, lo que representó un ahorro significativo de recursos y demuestra la factibilidad de utilizar fuentes administrativas en investigaciones de salud pública.

Otra fortaleza destacable fue la implementación de un riguroso proceso de verificación de la codificación diagnóstica, lo cual permitió asegurar la calidad de la información utilizada y refuerza la confiabilidad de los resultados obtenidos. Aunque los errores en las clasificaciones diagnósticas representan una posible fuente de sesgo, investigaciones previas han señalado que, si bien estos errores son relativamente frecuentes, no suelen afectar de manera significativa la estimación de la severidad de las lesiones ni la predicción de la mortalidad (128).

Otra de las principales fortalezas de este estudio radica en el uso de datos clínicos recolectados de manera sistemática en un centro de trauma de alta complejidad, lo cual garantiza la calidad y la fiabilidad de la información.

Se realizó un análisis estadístico robusto evaluando por primera vez en América Latina, el desempeño de escalas de trauma para predecir la supervivencia en una cohorte grande de niños. También por primera vez, se desarrollaron nuevos modelos predictivos con el objetivo de mejorar la precisión de los ya existentes, contribuyendo así al avance en herramientas de pronóstico aplicables en contextos pediátricos.

Los nuevos modelos fueron sometidos a validación interna mediante una potente técnica estadística, Bootstrap, lo que permitió evaluar su rendimiento de manera confiable, reduciendo el riesgo de sobreajuste.

Finalmente, la inclusión de una cohorte representativa de pacientes pediátricos en un contexto con alta carga de trauma violento aporta valor significativo. No solo contrasta con lo reportado en la mayoría de la literatura internacional, sino que también permite evaluar el desempeño de los modelos en un escenario poco explorado. Esta característica refuerza la necesidad de desarrollar modelos basados en datos regionales, que puedan servir como referencia para contextos con características epidemiológicas similares (118,119).

5.4 Limitaciones

Este trabajo presenta varias limitaciones que deben ser consideradas al interpretar sus hallazgos. En primer lugar, el diseño retrospectivo y monocéntrico puede introducir sesgos de selección y limitar tanto la generalización como la transportabilidad de los resultados. La realización de estudios prospectivos y multicéntricos en el futuro sería fundamental para reforzar la validez externa y la aplicabilidad clínica de los modelos evaluados.

En relación con el uso de diagnósticos codificados según la CIE-10, si bien los errores de codificación constituyen una posible fuente de sesgo, estudios previos han indicado que estos errores no suelen afectar de forma significativa la estimación de la severidad de las lesiones ni la predicción de la mortalidad (128). A pesar de ello, se implementó un proceso riguroso de verificación diagnóstica de los códigos CIE-10 para mitigar este riesgo.

Reconocemos la falta de información sobre la atención prehospitalaria, así como los datos de mortalidad en el entorno extrahospitalario. Considerando que una proporción considerable de las muertes relacionadas con trauma ocurre antes del ingreso hospitalario (129,130), la inclusión de estos datos en futuras investigaciones podría enriquecer el análisis de factores asociados a la mortalidad y mejorar la precisión de las estimaciones de supervivencia (127).

La elevada proporción de muertes por violencia interpersonal en adolescentes podría limitar la extrapolación de los resultados a otras regiones con una epidemiología distinta. No obstante, la inclusión de esta información resulta crucial para visibilizar una problemática real y vigente en América Latina, y representa un primer paso hacia el desarrollo de estrategias de intervención contextualizadas. Además, fortalece la pertinencia del modelo para contextos con alta carga de violencia, ofreciendo un marco de referencia útil para regiones con características similares.

La mortalidad fue la medida principal de desenlace. Sin embargo, consideramos que la inclusión de variables adicionales, como la morbilidad, las secuelas funcionales, la discapacidad o los desenlaces a largo plazo, permitiría evaluar integralmente el impacto del trauma en la calidad de vida de los pacientes pediátricos. Incluir estos desenlaces en futuras investigaciones contribuiría a una visión más amplia y centrada en el paciente.

5.5 Implicaciones para la práctica clínica y la investigación

Nuestra región atraviesa una situación crítica en términos de violencia, en la que niños y adolescentes representan una proporción significativa de las víctimas. Esta realidad refleja un problema profundo y multifactorial que exige un análisis reflexivo sobre nuestro rol como profesionales de la salud, investigadores y miembros de una sociedad violenta. Frente a este escenario, se requiere una respuesta activa mediante intervenciones multisectoriales, priorizadas e impulsadas por autoridades gubernamentales, sanitarias y académicas.

La investigación en trauma pediátrico debe fortalecerse como una prioridad científica y ética, orientada a generar conocimiento contextualizado, basado en datos robustos, que permita reconocer brechas asistenciales y fundamentar intervenciones que mejoren la supervivencia y calidad de vida de los pacientes pediátricos.

En este sentido, los hallazgos de esta tesis respaldan el uso sistemático de herramientas pronósticas como las escalas de trauma para estimar la probabilidad de supervivencia en niños lesionados. En particular, el PTS demostró un excelente desempeño en nuestra cohorte, lo que justifica su implementación como herramienta de triaje inicial en el contexto colombiano y latinoamericano. Su utilización puede optimizar el uso de los recursos sanitarios, evitando tanto la saturación de hospitales de alta complejidad con casos leves como el retraso en la atención de pacientes graves en instituciones sin capacidad resolutiva adecuada.

Por otra parte, como centros de alta complejidad que atendemos pacientes lesionados, tenemos la responsabilidad de implementar estrategias orientadas a mejorar la calidad de atención de nuestros pacientes. En consonancia con esto, la evaluación sistemática de resultados clínicos permite identificar factores asociados a desenlaces no esperados, lo que facilita intervenciones específicas para su corrección. En línea con este enfoque, el uso de herramientas pronósticas como las escalas de predicción de supervivencia y los indicadores estadísticos de desempeño (como los valores esperados versus observados, o DEF), empleados en nuestro estudio, han demostrado ser útiles a nivel internacional. Su incorporación en la práctica clínica podría fortalecer los procesos de auditoría, permitir comparaciones objetivas entre instituciones y contribuir a la mejora continua de la atención en trauma pediátrico.

Así mismo, nuestros datos también refuerzan la necesidad urgente de establecer un Sistema Nacional de Vigilancia de lesiones, que permita la recolección sistemática de información sobre la incidencia, causas, severidad y contexto de las lesiones, así como los procesos de atención y los desenlaces asociados, aplicando un abordaje de centros centinela. Contar con un sistema de este tipo facilitaría la planificación de estrategias preventivas efectivas, permitiría mejorar la calidad de atención al identificar deficiencias, y reduciría la carga sanitaria y económica generada por la morbilidad y mortalidad por trauma. Además, contribuiría significativamente a la investigación en la medida que aporta nuevo conocimiento, esencial para la formulación de políticas basadas en evidencia y para el diseño de intervenciones más eficaces. Este sistema de vigilancia se constituiría, por tanto, en una herramienta fundamental de salud pública para mejorar la salud poblacional.

Finalmente, esta evidencia pone de manifiesto la necesidad de fortalecer la formación en trauma pediátrico en los programas de pregrado, posgrado y educación continua del personal de salud, así como de fomentar el trabajo colaborativo entre sectores. Las estrategias de intervención deben tener un enfoque preventivo, multidisciplinario e intersectorial, abordando las causas estructurales de la violencia y promoviendo entornos seguros para la niñez y la adolescencia.

6. CONCLUSIONES

- La mayoría de los fallecimientos ocurrió en adolescentes entre los 10 y 17 años, y el 71% de ellos fue a causa de un homicidio. Sin embargo, se registraron muertes por esta causa desde el primer año de vida, lo que evidencia un desafío crítico para la salud pública en la región.

- Las muertes se concentraron en hombres de bajo nivel socioeconómico, con lesiones por arma de fuego, lo que no solo resalta la naturaleza violenta del trauma, sino también su estrecha relación con determinantes sociales que incrementan la vulnerabilidad de ciertos grupos poblacionales.

- El trauma craneoencefálico fue la principal causa de muerte, independientemente de la intencionalidad del mecanismo lesional, lo que subraya la necesidad de estrategias específicas para su prevención y manejo.

- El PTS mostró un excelente desempeño en la predicción de supervivencia, con resultados consistentes en todas las métricas de evaluación analizadas.

- La incorporación de variables como la edad y la Escala de Coma de Glasgow (ECG) en los modelos de predicción mejora su precisión pronóstica, especialmente en la población pediátrica. Esto responde no solo a las características epidemiológicas de este grupo etario, sino también a sus particulares respuestas fisiológicas adaptativas frente al trauma.

- Dadas las características de la cohorte y los resultados obtenidos, los modelos evaluados presentan un potencial considerable para su uso en contextos similares en América Latina, donde predominan condiciones epidemiológicas y estructurales comparables.

- Se requiere validar nuestros hallazgos en otras poblaciones pediátricas para determinar su aplicabilidad y fortalecer su utilidad como herramienta de apoyo en la toma de decisiones clínicas y de políticas públicas.

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