Journal of Pediatric Surgery 55 (2020) 1245–1248

Contents lists available at ScienceDirect

Journal of Pediatric Surgery

journal homepage: www.elsevier.com/locate/jpedsurg

Validation of the PRESTO score in injured children in a South-African quaternary trauma center☆,☆☆

Etienne St-Louis [b,d,*,1], Rubesh Hassamal [a,1], Tarek Razek [b], Robert Baird [c], Dan Poenaru [b,d], Timothy C. Hardcastle [a]

[a] Department of Surgery and Trauma service, Nelson R Mandela School of Clinical Medicine, University of Kwa-Zulu Natal, Durban, South Africa
[b] Centre for Global Surgery, McGill University Health Centre, Montreal, Canada
[c] Division of Pediatric General and Thoracic Surgery, University of British Columbia, Vancouver, Canada
[d] Division of Pediatric General and Thoracic Surgery, Montreal Children's Hospital, McGill University Health Centre, Montreal, Canada

ARTICLE INFO

Article history:
Received 13 March 2019
Received in revised form 1 August 2019
Accepted 7 August 2019

Key words:
Risk-adjustment
Benchmarking
Severity
Performance, quality
Outcomes

ABSTRACT

Introduction: The Pediatric RESuscitation and Trauma Outcome (PRESTO) model was developed for standardized risk-adjustment in pediatric trauma and is adapted to low-resource settings. It includes easily-accessible demographic and physiologic variables that are available at point of care in virtually any setting. The purpose of this study was to evaluate the PRESTO model's ability to predict in-hospital mortality in a South African pediatric trauma unit by comparing it to the widely used Injury Severity Score (ISS).
Methods: Data prospectively collected between 2007 and 2017 in the Inkosi Albert Luthuli Central Hospital Trauma Registry were retrospectively reviewed. Injured children younger than 14 years were included if they were admitted to hospital or died as a result of their injury. We excluded patients with minor injuries who were treated and discharged home and patients with incomplete hospital disposition data. Receiver-Operating Characteristic (ROC) curves were constructed for PRESTO and ISS, and the areas under the curve (AUCs) were compared using Delong's test. The sensitivity and specificity of PRESTO were calculated at different prognostic threshold values identified through literature review.
Results: We identified 419 patients; 67 died in hospital (16%). The AUCs for PRESTO and ISS were 0.82 (95% confidence interval CI [0.76–0.87]) and 0.75 (CI [0.68–0.81]), respectively. This difference trended towards statistical significance ($p = 0.07$). Using the optimal threshold of 0.13 described in the original publication, PRESTO had a 97% sensitivity and 37% specificity, while a threshold of 0.50 yielded 90% sensitivity and 54% specificity. The mean predicted probability of in-hospital death among patients who died was 0.79. Using this value as a threshold yielded the 57% sensitivity and 85% specificity.
Conclusion: This analysis has demonstrated the validity of the PRESTO model for in-hospital mortality prediction for pediatric trauma patients in the setting of a dedicated high-complexity trauma unit in a South African trauma referral center.
Level of evidence: Level III: Case–control.

Morbidity and mortality from trauma disproportionately affect pediatric populations in low- and middle-income countries (LMICs). [1] In South Africa, the burden of pediatric trauma may be underestimated as the majority of available reports are hospital-based. [2–4,6] These typically do not include children treated by traditional healers or those who died as a result of their injury before arrival to the hospital. [7] South African statistics from 2016 showed that approximately 26% of deaths in the 1–14 year-old age group were caused by accidents and injuries. [8] This surpasses the proportion of deaths caused by tuberculosis (3.4%), human immunodeficiency virus (2.5%), intestinal infectious disease (6.6%) and malnutrition (3.7%) in the same age group. Injury surveillance mechanisms and quality improvement initiatives aimed at decreasing the burden of trauma-related mortality must therefore be adapted to the pediatric population as well. Although dedicated pediatric trauma centers exist in South Africa, most pediatric trauma is managed in adult trauma centers or other centers with varying levels of capacity. [7] For benchmarking of institutional performance in the management of injured children, it is therefore important to have a standardized way of quantifying the severity of childhood injury. [10] However, it has been shown that many existing trauma scores are poorly adapted to the unique physiology of children and can be overly reliant on inconsistently available resources. [11]

☆ Funding: Etienne St-Louis is supported by the Fonds de Recherche en Santé Québec and the McGill University Division of General Surgery Surgeon Scientist Program.
☆☆ Declaration: All authors declare no conflicts of interest.
* Corresponding author at: McGill University Health Centre – Glen Site, 1001 Decarie Boulevard B.04.2455-1. Tel.: +1 514 934 1934.
E-mail address: etienne.st-louis@mail.mcgill.ca (E. St-Louis).
[1] *Indicates co-first authors*

https://doi.org/10.1016/j.jpedsurg.2019.08.008
0022-3468/

Table 1
Baseline patient characteristics.

Variable	Count (Proportion)	Median (Interquartile range)
Age	-	6 (4–9)
Female sex	179 (43%)	-
Systolic blood pressure	-	110 (98–121)
Pulse rate	-	117 (100–135)
Oxygen saturation	-	100 (99, 100)
Invasive airway intervention	269 (64%)	-
Neurologic Status		-
Alert	130 (31%)	
Verbal stimuli responsive	71 (17%)	
Painful stimuli responsive	175 (42%)	
Unresponsive	43 (10%)	
Injury Severity Score	-	25 (16–34)

In 2016, a new "low-tech" model was developed to predict the in-hospital mortality of injured children using basic physiologic and demographic variables. This Pediatric RESuscitation and Trauma Outcome (PRESTO) model was developed using the American College of Surgeons (ACS) National Trauma Data Bank (NTDB) [12] and later calibrated using a low-income country trauma database. [13] The variables which constitute the PRESTO model include age, selected vital signs in the emergency department (heart rate, presence or absence of age-specific hypotension, oxygen saturation, AVPU neurological status), and need for invasive airway intervention (intubation or surgical airway). However, PRESTO has yet to be prospectively validated in an LMIC setting. [13]

The purpose of this study was to validate the PRESTO model using prospectively collected trauma data from a quaternary South African trauma unit. We hypothesized that the PRESTO model is a valid predictor of in-hospital mortality and outperforms the Injury Severity Score (ISS), which is currently used for standardized injury severity assessment in this setting. [14]

1. Methods

1.1. Study setting and design

This was a retrospective study set at the Inkosi Albert Luthuli Central Hospital, a referral Level 1 Trauma center of the University of Kwa-Zulu Natal (UKZN), in South Africa. Ethics approval was provided by the UKZN Biomedical Ethics Research Committee in November 2017 (*BCA207/09*). Data were collected from a prospectively-maintained UKZN trauma registry.

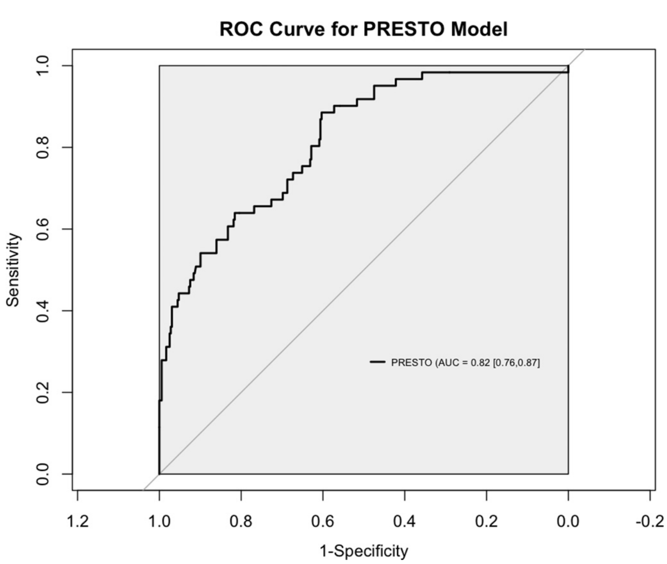

Fig. 1. Receiver-operating-characteristic curve of PRESTO model in South African sample of pediatric trauma patients.

Table 2
Sensitivity, specificity, and AUC of the PRESTO model using various threshold values of expected mortality (EM).

Threshold	Sensitivity	Specificity	AUC
T = 0.129	97%	37%	0.816
T = 0.500	90%	54%	0.816
T = 0.789	57%	85%	0.816

1.2. Patient selection and data collection

Eligible patients were identified from the trauma registry in the period spanning from January 1st, 2007 to December 31st, 2017. Patients were included if they were aged 14 years or less, had been admitted to hospital for management of their injuries, or died as a result of their injuries. Patients who were aged 15 years or more and those who sustained minor injuries not requiring hospitalization were excluded. Patient age, sex, emergency department vital signs, airway interventions, neurologic status, ISS, and disposition after hospitalization were collected. Missing data were assumed to be missing not-at-random and were addressed using multiple imputations. [15]

1.3. Data analysis

Patient characteristics were summarized using descriptive statistics, including counts, proportions, medians and ranges, as appropriate. Expected probability of in-hospital mortality (EM) was calculated using the PRESTO model for each patient. Receiver-operating-characteristic (ROC) curves were constructed for the PRESTO model and ISS scores; their areas-under-curve (AUCs) were calculated and compared using Delong's test with 2000 bootstrap iterations for cross-validation. [16] The sensitivity and specificity of PRESTO for predicting in-hospital mortality were calculated using three different thresholds of EM: the optimal threshold $T = 0.129$ described in the original development of PRESTO [12], a sensible threshold of $T = 0.500$, and a threshold based on the median EM in patients who died in this sample. The chi-squared test was used to compare the proportion of in-hospital deaths between categories of injury severity based on ISS. [14] Statistical significance was set a $p = 0.05$. All statistical analyses were performed using R version 3.4.3 [17] (Auckland, New Zealand).

2. Results

2.1. Patient characteristics

A total of 419 pediatric trauma patients were included in the study, 240 males (57%) and 179 females (43%). The median age of our patient population was 6 years. The ISS classification was mild (ISS < 9) for 8.4% of patients, moderate (ISS 9–15) for 13.1%, severe (ISS 16–24) for 21.2% and profound (ISS ≥ 25) for 57.3%. The observed proportion of in-hospital deaths in this sample was 16% (67/419). The mean EM based on PRESTO modeling was 47%. Full baseline patient characteristics are presented in Table 1.

2.2. PRESTO validation

The ROC curve for PRESTO is shown in Fig. 1. The AUC for PRESTO was 0.82 (95% confidence interval [0.76–0.87]). The diagnostic performance characteristics of the PRESTO model in this sample varied based on the selected threshold, as shown in Table 2. Using the optimal threshold of $T = 0.129$ identified in the PRESTO development paper [12], PRESTO had a sensitivity of 97% and a specificity of 37%. A sensible threshold of $T = 0.500$ yielded a sensitivity of 90% and a specificity of

Table 3
Proportion of in-hospital deaths by ISS classification.

Injury severity score (ISS) classification	Number of patients (as proportion of full sample)	Number of in-hospital deaths (as proportion of patients in ISS class)	p-value
Mild (ISS < 9)	35 (8%)	1 (3%)	-
Moderate (ISS 9–15)	55 (13%)	1 (2%)	0.763
Severe (ISS 16–24)	89 (21%)	6 (7%)	0.396
Profound (ISS ≥ 25)	240 (57%)	61 (25%)	0.004

54%. The mean EM among patients who died in-hospital was 79%. Using this threshold of 0.789, the sensitivity was 57% and the specificity 85%.

2.3. Comparison of PRESTO and ISS

The proportion of in-hospital deaths increased as a function of ISS classification, as shown in Table 3. Overall, the AUC for the ISS was 0.75 (95% confidence interval [0.68–0.81]), which was lower than the AUC for the PRESTO model, as shown in Fig. 2. This difference trended towards statistical significance ($p = 0.07$).

3. Discussion

This study has found that the PRESTO model is a valid predictor of in-hospital mortality in South African pediatric trauma patients treated in a high-acuity trauma referral center. We also demonstrated that the PRESTO model has superior goodness-of-fit compared to the well-established ISS score, although this was not statistically significant. ISS, which relies on precise anatomic diagnoses and is currently being used to classify injury severity in the setting of this study, may not be universally applicable in LMICs. [11] Furthermore, ISS requires identification of all injuries prior to estimation of expected mortality, while the PRESTO model uses simple physiologic and demographic variables that are available at point of care in virtually any setting, including health facilities with basic or limited capacity. [13] We therefore believe that PRESTO is advantageous for quality improvement for pediatric trauma in low-resource settings, not only because the PRESTO model has been shown to be a valid predictor of in-hospital death, but also because it is user friendly in this environment and it is adapted to children.

When interpreting the results of this study, it is important to carefully consider the characteristics of the patients in our sample as well as the particularities of the setting from which the sample was obtained.

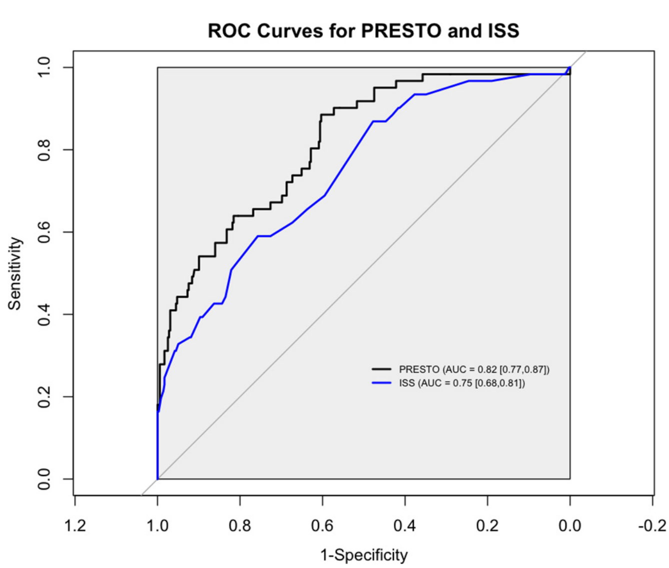

Fig. 2. Receiver-operating-characteristic curve of PRESTO model vs. ISS in South African sample of pediatric trauma patients.

Generally speaking, most registry-based studies, such as this one, fail to account for the prehospital mortality attributable to nonexistent or inadequate prehospital trauma systems. [18,19] The database used in this study does not include prehospital data such that we cannot comment explicitly on this hidden mortality or on the trauma system performance as a whole. We simply do not have these data. In this particular context, however, prehospital care is prioritized for children by the emergency medical services (EMS) and special pediatric EMS vehicles are available in most of South Africa. Inkosi Albert Luthuli Central Hospital (IALCH) is a level 1 trauma unit, which serves as a lead hospital and works with several level 2, 3, and 4 trauma centers to optimize resource and expert care to all the injured patients in the province of Kwa-Zulu Natal. The cooperative environment between the institutions allows the patients to flow between hospitals depending on resources and clinical expertise matched to the patient's need. The majority of pediatric pedestrian–vehicle collision victims who are referred to IALCH trauma unit are severely injured, requiring intensive care and multispecialty interventions that cannot be provided at base hospitals [20–22]. A large proportion of patients are transferred already intubated from these institutions. This decreases our ability to compare PRESTO to other commonly used injury scoring systems which require evaluation of respiratory rate, such as the Revised Trauma Score (RTS) or the Kampala Trauma Score (KTS). [23,24]

The KTS has been widely adopted as a risk-adjustment tool for trauma patients in low-resource settings. [10] Originally developed in Uganda, it has since been validated in multiple LMICs. [25–27] However, closer examination of the KTS constituent variables reveals physiologic cutoff values that are not applicable to young children. Although the original KTS development study reports validity in a cohort of adult and pediatric patients, there has never been a study examining the discriminatory ability of KTS in a standalone pediatric trauma population. [11,22] A recent study compared PRESTO to KTS in a prospectively collected pediatric trauma database in Rwanda and reported that PRESTO significantly outperforms KTS in the ability to predict in-hospital mortality in injured children 5 years-old or younger. Furthermore, the same study showed improved performance of PRESTO over RTS in all children aged 14 years or younger. [13]

To illustrate a potential application of PRESTO in pediatric trauma outcomes benchmarking, we calculated the mean EM in this sample to be 45%. Notably, the observed mortality (OM) in this study was 16%. This situation therefore suggests high institution performance in the management of trauma performance, as the EM significantly exceeds the OM threefold. Having a standardized patient risk-adjustment metric such as PRESTO, which is adapted to the population and appropriate for the environment, remains critical for effective quality improvement. It has been well described that multiple nonpatient factors correlate with variations in survival after traumatic injury across health-care facilities, including the existence of effective prehospital systems [28], the institutional experience (or volume) and preparedness for severe trauma management [29], as well as the availability of critical resources such as blood products, antibiotics, skilled surgical teams, and intensive care capability. [30] An integral trauma outcomes benchmarking model must therefore include objective assessments of the institution's capacity and accessibility within the trauma system as a whole in addition to what PRESTO can provide with respect to essential patient-level risk-adjustment.

This study is limited by the small sample size, which precluded subgroup analyses. A ratio of 10 outcome cases per predictive variable is typically accepted for prediction model validation. [31] The PRESTO model has 6 component variables, therefore our study sample containing 67 deaths was sufficient. The prospective trauma registry from which data were sourced for this study undergoes periodic auditing for patient capture, data quality and completeness. Despite these efforts, inconsistencies in the timing and accuracy of recorded data within the registry could not be accounted for in this analysis.

Finally, we recognize the computational burden of PRESTO, which may discourage potential users from integrating this model. This has been described as a limitation of other predictive models based on logistic regression, the complexity of which may limit their utility in a clinical setting. [32] Increasing global collaboration will influence and improve the implementation and validation of new trauma scoring systems, and mobile health technology such as phone apps can significantly assist. [33,34]

Future directions for this research thus include the creation of an intuitive and user-friendly smart-phone app allowing clinicians or researchers to calculate the EM by directly entering the six required patient variables. [33] More technologically advanced systems could even integrate this back-end calculation into existing electronic medical records to decrease the computational burden on the primary user.

4. Conclusion

This analysis has demonstrated the validity of the PRESTO model for in-hospital mortality prediction for pediatric trauma patients in the setting of a dedicated high-complexity trauma unit in a South African quaternary referral center. The PRESTO model, which is made up only of demographic and physiologic variables obtainable in virtually all settings, performed equivalently to the ISS in predicting in-hospital mortality for injured children, with a statistically nonsignificant trend towards improved discrimination. PRESTO may have the potential to serve an important role in standardized patient-level risk-adjustment for pediatric trauma outcomes-benchmarking in low-resource settings. Further validation of the PRESTO model is needed from other LMICs to increase the generalizability of this tool.

CRediT authorship contribution statement

EtienneSt-Louis: Conceptualization, Formal analysis, Writing - original draft, Writing - review & editing. **Rubesh Hassamal:** Conceptualization, Data curation, Formal analysis, Writing - original draft, Writing - review & editing. **Tarek Razek:** Writing - review & editing. **Robert Baird:** Writing - review & editing. **Dan Poenaru:** Writing - review & editing. **Timothy C. Hardcastle:** Conceptualization, Writing - review & editing.

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