Validation of Age-specific Survival Prediction in Pediatric Patients With Blunt Trauma Using Trauma and Injury Severity Score Methodology: A Ten-year Nationwide Observational Study

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Abstract

Background: In-hospital mortality in trauma patients decreased recently owing to improved trauma injury prevention systems. However, no study which evaluated the validity of Trauma and Injury Severity Score (TRISS) in pediatrics by detailed classification of patients' age and injury severity in Japan. This retrospective nationwide study evaluated the validity of TRISS in predicting survival in Japanese pediatric patients with blunt trauma by age and injury severity.

Methods: Data were obtained from the Japan Trauma Data Bank during 2009–2018.

Results: In all age categories, the area under the curve (AUC) for TRISS demonstrated high performance (0.935, 0.981, 0.979, and 0.977). The Accuracy of TRISS was 99.9%, 98.2%, 92.1%, 76.7%, 55.3%, and 72.1% in survival probability (Ps) interval groups (0.96–1.00), (0.91–0.95), (0.76.–0.90), (0.51–0.75), (0.26–0.50), and (0.00–0.25), respectively. The AUC for TRISS demonstrated moderate performance in the Ps interval group (0.96–1.00) and low performance in other Ps interval groups.

Conclusions: The TRISS methodology appears to predict survival accurately in Japanese pediatric patients with blunt trauma; however, there were several problems in adopting the TRISS methodology for younger blunt trauma patients with higher injury severity. In the future, we should consider to conducting a simple, high-quality prediction model that is more suitable for pediatric trauma patients than the current TRISS model.

Background

Trauma scoring methods for survival prediction in trauma patients are essential to assess the quality of trauma care because they permit valid comparison of trauma patients who have different anatomical and physiological severities [1]. The Trauma and Injury Severity Score (TRISS) method has been commonly used to calculate the statistical survival probability in trauma patients since its introduction in 1987 by Boyd et al. [2]. After the validation of the revised-version of TRISS by the American College of Surgeons Committee on Trauma coordinated Major Trauma Outcome Study (MTOS) [3,4] in the Japanese cohort, the TRISS method is reported as a standard technique for estimating survival probability and has commonly been used for evaluating the quality of trauma care [5–8].

The accuracy of the TRISS method, nevertheless, has various challenges by investigated area, time, and age. [9–13]. First, previous studies suggested that the TRISS has a low accuracy for survival prediction in patients with higher severity of injury or in younger pediatric patients [9,10]. Second, previous studies suggested that there is a trend to improve the observed-to expected mortality ratio in major trauma patients, and therefore, new coefficients should be calculated according to these improvements in trauma care for the TRISS to maintain the accuracy for survival prediction [9,11]. Finally, there are also studies indicating that the modified TRISS methodology with local database-derived coefficients might enhance the accuracy of survival prediction in all regions except the USA, wherein the original TRISS methodology was developed because there are marked differences by region such as in Asian countries [12,13].

Although birth rate and mortality of the Japanese population has changed yearly [8,14], to the best of our knowledge, no study has evaluated the validity of the TRISS method in a pediatric cohort by detailed classification of patients' age and severity in Japan. Therefore, this study aimed to evaluate the validity of the TRISS method in predicting the survival of Japanese pediatric patients with blunt trauma by detailed classification of age (neonates/infants, pre-school children, schoolchildren, and adolescents) and severity of injury. This study analyzed data obtained from the Japan Trauma Data Bank (JTDB) [6] for the 10-year study period during 2009–2018.

Methods

Study Setting and Population

This retrospective, nationwide, observational study analyzed data obtained from the JTDB, which registers data of patients with trauma and/or burn and records prehospitalization and hospital-related information. The JTDB records data of demographics, comorbidities, injury types, mechanism of injury, means of transportation, vital signs, Abbreviated Injury Scale (AIS) score, Injury Severity Score (ISS), prehospital/in-hospital procedures, trauma diagnosis as indicated using the AIS, and clinical outcomes. In most cases, physicians who are trained in AIS coding by using the 1990 revision of AIS (AIS90) [15] undertake the online registration of individual patient data. The Japan Association for the Surgery of Trauma permits open access and update of existing medical information, and the Japan Association for Acute Medicine evaluates the submitted data [6].

Figure 1 shows a flow diagram of the patient disposition. In this study, we used a JTDB dataset that included information for the period January 1, 2009, to December 31, 2018, which initially yielded the data of 313,643 patients. The inclusion criteria for this study were as follows: presence of trauma and age below 18 years. Patients aged more than 19 years, with burns or penetrating trauma, with cardiac arrest on hospital arrival, or with missing data of outcome and TRISS prediction were excluded from this study. Among 26,329 patients with blunt trauma and younger than 18 years, 2,480 (9.4%) patients had missing data of survival and 5,446 (20.7%) patients had missing date of TRISS predictor, and hence, the survival probability (Ps) was not calculated using the TRISS method. Furthermore, 683 (2.6%), 1,948 (7.4%), 1,608 (6.1%), and 3824 (14.5%) patients had missing data of ISS, Glasgow Coma scale (GCS) score, systolic blood pressure (sBP), and respiratory rate (RR), respectively. Table S1 shows the number of patients who had missing data by age category and each variable.

Data collection

We collected information of following variables from the JTDB: age (years), sex, AIS, AIS of the injured region, Revised Trauma Score [3], ISS [10], Ps, and in-hospital mortality. The TRISS ranges from 0 (certain death) to 1 (certain survival), and the survival probability (Ps) is calculated as follows:

$$\text{TRISS} = \text{Ps} = 1/(1 + e^{-b})$$

where b=b0+b1(RTS)+b2(ISS)+b3(age).

RTS is calculated using the GCS score, the sBP, and the RR.

$$\mathrm{RTS} = 0.9368 * \mathrm{GCS} + 0.7326 * \mathrm{sBP} + 0.2908 * \mathrm{RR}$$

Data analysis

The estimated study outcomes were as follows: (1) patients' characteristics and mortality by age groups (neonates/infants aged 0year, pre-school children aged 1–5 years, schoolchildren aged 6–11 years, and adolescents aged 12–18 years), (2) validity of Ps assessed using the TRISS methodology by the four age groups and six Ps-interval groups (0.00–0.25, 0.26–0.50, 0.51–0.75, 0.76–0.90, 0.91–0.95, and 0.96–1.00), and (3) the observed/expected survivor ratio by age- and Ps-interval groups . In the primary analysis, which was conducted to identify the characteristics of pediatric trauma patients during the study period, a Mann–Whitney U test and Kruskal–Wallis test were used for analyzing continuous variables, whereas a chi-square test was used for analyzing categorical variables. In the secondary analysis, the validity of TRISS was evaluated by the predictive ability of the TRISS method using the receiver operating characteristic (ROC) curves presents the sensitivity, specificity, positive predictive value, negative predictive value, accuracy, area under the receiver operator characteristic curve (AUC), and it's 95% confidence interval (CI) of TRISS and shows the ability of TRISS to distinguish between positive and negative outcome. The AUC varies as < 0.7 (low performance), 0.7–0.9 (moderate performance), and > 0.9 (high performance). In the third analysis, the expected survival calculated using TRISS Ps was compared with the actual Ps. The expected number of survivors in each Ps-interval group was calculated by integrating mean Ps and the number of patients for six Ps-interval group. The results of these comparisons are expressed as the medians and interquartile ranges (IQRs; 25th–75th percentile) for continuous variables and as the mean and percentages for categorical variables. All statistical analyses were performed using STATA/SE software, version 16.0 (StataCorp; College Station, Texas, USA). A two-tailed P-value of less than 0.05 indicated statistical significance.

Results

During the 10-year study period, the data of 17,745 pediatric patients with blunt trauma were included in this study (Figure 1). These patients were categorized into the following age groups: neonates/infants (N = 330, 2%), pre-school children (N = 2183, 12%), schoolchildren (N = 5950, 34%), and adolescents (N = 9282, 52%). The median age and Ps of the total cohort were 13 years (IQR, 8–17) and 0.99 (IQR, 0.98–0.99), respectively. The overall in-hospital mortality rate was 2.1 %.

Table 1 shows the demographic and characteristics and variables by age. There were significant differences in all variables by age category, except for neck injury with AIS ≥ 3. Neonates/infants had the highest percentage of head injury with AIS ≥ 3 (88%), highest mean ISS, lowest RTS, and lowest median Ps compared to those of the other age categories.

Table 2 shows the accuracy and AUC of TRISS for each age category. The accuracy of the TRISS model by age group was 96.4% in neonates/infants, 98.0% in pre-school children, 99.0% in schoolchildren, and 97.9% in adolescents. In all age categories, the AUC of TRISS demonstrated high performance (0.935, 0.981, 0.979, and 0.977).

Table 3 shows the accuracy and AUC of TRISS by each Ps-interval group. The accuracy of the TRISS model by the Ps-interval groups was 99.9% in Ps interval (0.96–1.00), 98.2% in Ps interval (0.91–0.95), 92.1% in Ps interval (0.76.–0.9), 76.7% in Ps interval (0.51–0.75), 55.3% in Ps interval (0.26–0.50), and 72.1% in Ps interval (0.00–0.25). The AUC of TRISS demonstrated moderate performance in the Ps interval (0.96–1.00) group (AUC, 0.865); however, the AUC of TRISS demonstrated low performance in other Ps interval groups.

Table 4 shows the observed-to-expected survivor ratio in the Ps interval by age category. In all age categories, the observed survivors among patients with Ps-interval (0.00–0.25) were 1.5 times or more than the expected survivors calculated using the TRISS method.

Discussion

This study showed that the TRISS methodology had high performance in survival prediction for paediatric patients with blunt trauma. However, there were differences in the validity of TRISS in the subgroup analysis. Among neonates/infants with blunt trauma, the AUC for TRISS was lower than that of other age categories. Moreover, the TRISS model had low performance in survival prediction for pediatric patients with Ps ≤ 0.95, and TRISS underestimated expected survivors in pediatric patients with Ps ≤ 0.25.

Because the accuracy of the TRISS model may reflect the influence of demographic differences in trauma such as the trauma care system or the population structure between the sample area and the USA, wherein the TRISS method was developed, local database-derived coefficients may further enhance the predictive performance of TRISS [12,13,16,17]. Previous studies based on a Japanese cohort, including children registered in the JTDB during 2005–2008 and 2009–2013 proved that the AUC of TRISS was 0.962 and 0.948 [9,17]. These Japanese studies focused on paediatric patients with blunt trauma and demonstrated that the TRISS had a high performance only for Japanese pediatric patients, as in a previous study [9,17]. Although it is difficult to compare the results between previous studies and this study because of the different periods when the studies were conducted, our results suggest that the TRISS model may be appropriate for Japanese pediatric patients with blunt trauma. However, there is no unified consensus whether TRISS is a suitable prediction model for pediatric patients. One study recommended the use of the TRISS methodology for both adult and pediatric patients because both TRISS models with and without pediatric coefficients equally predict survival with high performance in pediatric patients with blunt trauma [13,18]. In the other study, the TRISS model had significantly lower performance than the revised TRISS model based on age-adjusted weights (AUC, 0.785 vs. 0.985, $p < 0.05$)) [10,19]. Our results suggest several problems in adopting the TRISS model for pediatric blunt trauma patients of all ages or all severity, although our results showed that TRISS had high performance in the overall pediatric cohort.

In this subclass analysis by age category, the accuracy of the TRISS model for neonates/infants was lower than that of the other age categories. One of the reasons was considered that the neonate/infant group sustained the largest proportion of severe head injury with ISS ≥ 3 in this study. A previous study showed that the accuracy of the TRISS model for trauma patients with head injury or younger than 5 years was significantly inferior to that for the other pediatric-specific model [10]. One other reason was considered to be the largest rate of missing data in the neonate/infant group, which are needed for validating the accuracy of TRISS, such as survival outcome and TRISS predictors. Table S1 shows the rate of missing data by age category in the JTDB dataset. The number of neonates/infants with blunt trauma was lowest (N=771, 2.9% of all), but the proportion of patients with missing data on survival and TRISS prediction was largest (53.7% of neonate/infants with blunt trauma). These might have adverse effect on the prediction accuracy of TRISS in neonates/infants. Therefore, a dataset with high-quality and without missing data should be constructed to improve the accuracy of TRISS in predicting the survival of pediatric patients. In this study, among the TRISS predictors, younger pediatric patients had missing data for larger physiological status parameter such as GCS, sBP, or RR. There is a possibility of bias while evaluating the physiological status in younger pediatric patients. A Previous study indicated that the evaluation of consciousness using GCS in children younger than 5 years is challenging owing to their limited verbal communications and motor responses; therefore, simplified evaluation tools such as AVPU score (A, Alert; V, responsive to Verbal stimulus; P, responsive to Painful stimulus; U, Unresponsive) instead of GCS, suggested to facilitate evaluation and improvement of data quality in younger children [20]. Furthermore, a previous study showed that RR data, which are missing in most cases in the JTDB in the Japan JTDB dataset, might be less needed for the calculation of TRISS Ps in accuracy [9,17,21]. It may be necessary to construct the modified TRISS model or new prediction model with higher accuracy and suitable for the Japanese situation based on validation of the Japanese dataset. A previous study suggested that a simplified prediction model that requires only easily collected data and fewer missing data will facilitate the evaluation and improvement of the accuracy of the model [22].

In the subclass analysis by TRISS Ps-interval groups, the accuracy of the TRISS model for patients with Ps ≤ 0.95 did not have high performance and the observed-to expected mortality ratio in pediatric patients with Ps ≤ 0.25 was 2.15. Previous studies also suggested similar results, which are as follows: TRISS had lower performance in Japanese blunt trauma patients with Ps < 0.9 than those with Ps ≥ 0.9 [9] and TRISS underestimates survival for pediatric trauma patients with TRISS Ps ≤ 91% [10]. Previous studies suggested that the decreasing trend of in-hospital mortality among trauma patients decreased in recent years would lead the TRISS model to be out of calibration [8,11]. Previous studies conducted using the JTDB data suggested that improvements in trauma care and trauma care systems account for decreasing mortality, especially in major trauma after the Japan Advanced Trauma Evaluation and Care was introduced in 2002 [7,8,23]. Therefore, our results may suggest that new coefficients related to injury severity should be calculated periodically to keep up with changes in trauma care in their own country.

Our study had several limitations. First, there was a selection bias because not all Japanese hospitals that treat have registered in the JTDB. In addition, the number of participating hospitals differed across the study period. Furthermore, pediatric blunt trauma patients younger than 18 years whose data were registered in the JTDB (N=7926, 30.1%) had missing data on important variables, although selection bias occurred in the data set with more than 10% missed rate [21]. Although this study population represents the Japanese trauma experience, our results may be nearly close to those obtained in many other Asian countries such as South Korea, Hong Kong, and Thailand, where trauma patient demographics are similar [12,17,24]. Our study attempted to utilize cross-validation procedures to assess the validity of the results obtained from our results. In the next step, based on these results, we would like to conduct a regression model that is more suitable to the country's situation, and a new regression model would improve the quality of trauma care in that country, contributing to a decrease in the number of preventable trauma deaths.

Conclusions

This study showed that overall the TRISS methodology appears to accurately predict survival in Japanese pediatric patients with blunt trauma. However, there were several problems in adopting the TRISS model for blunt trauma patients who are younger and/or with higher injury severity. In the future, we should consider conducting a simple new prediction model with high-quality, which is more suitable for pediatric trauma patients than the current TRISS model.

List Of Abbreviations

TRISS, Trauma and Injury Severity Score; AUC, area under the curve; Ps, survival probability; MOTS, Major Trauma Outcome Study; JTDB, Japan Trauma Data Bank; AIS90, AIS, Abbreviated Injury Scale; ISS, Injury Severity Score; 1990 revision of AIS; GCS, Glasgow Coma scale; sBP, systolic blood pressure; RR, respiratory rate; ROC, receiver operating characteristic; CI, 95% confidence interval; IQRs, interquartile ranges.

Declarations

Ethics approval and consent to participate:

This study was approved by the Institutional Ethics Committees of Yokohama City University Medical Centre (approval no. B170900003). The approving authority for data access was the Japanese Association for the Surgery of Trauma (Trauma Registry Committee). The need for informed consent from the patients was waived due to the observational nature of the study design.

Consent for publication:

Not applicable.

Availability of data and materials:

The datasets supporting the conclusions of this article are available from the corresponding author on reasonable request.

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Authors' contributions:

Conceptualisation C.T. and T.M., methodology C.T., software C.T. and T.A.., validation C.T. T.M. T.A. M.G. and M.S., formal analysis C.T., investigation C.T. T.M. T.A. M.G. and T.A., resources C.T. and T.A., data curation C.T. and T.A., writing—original draft preparation C.T., writing—review and editing C.T. T.M. T.A. M.G. T.A. I.T. and N.M., visualisation C.T., supervision N.M., project administration and funding acquisition C.T. All authors have read and agreed to the final version of the manuscript.

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Tables

Due to technical limitations, table 1-4 is only available as a download in the Supplemental Files section.

Figures

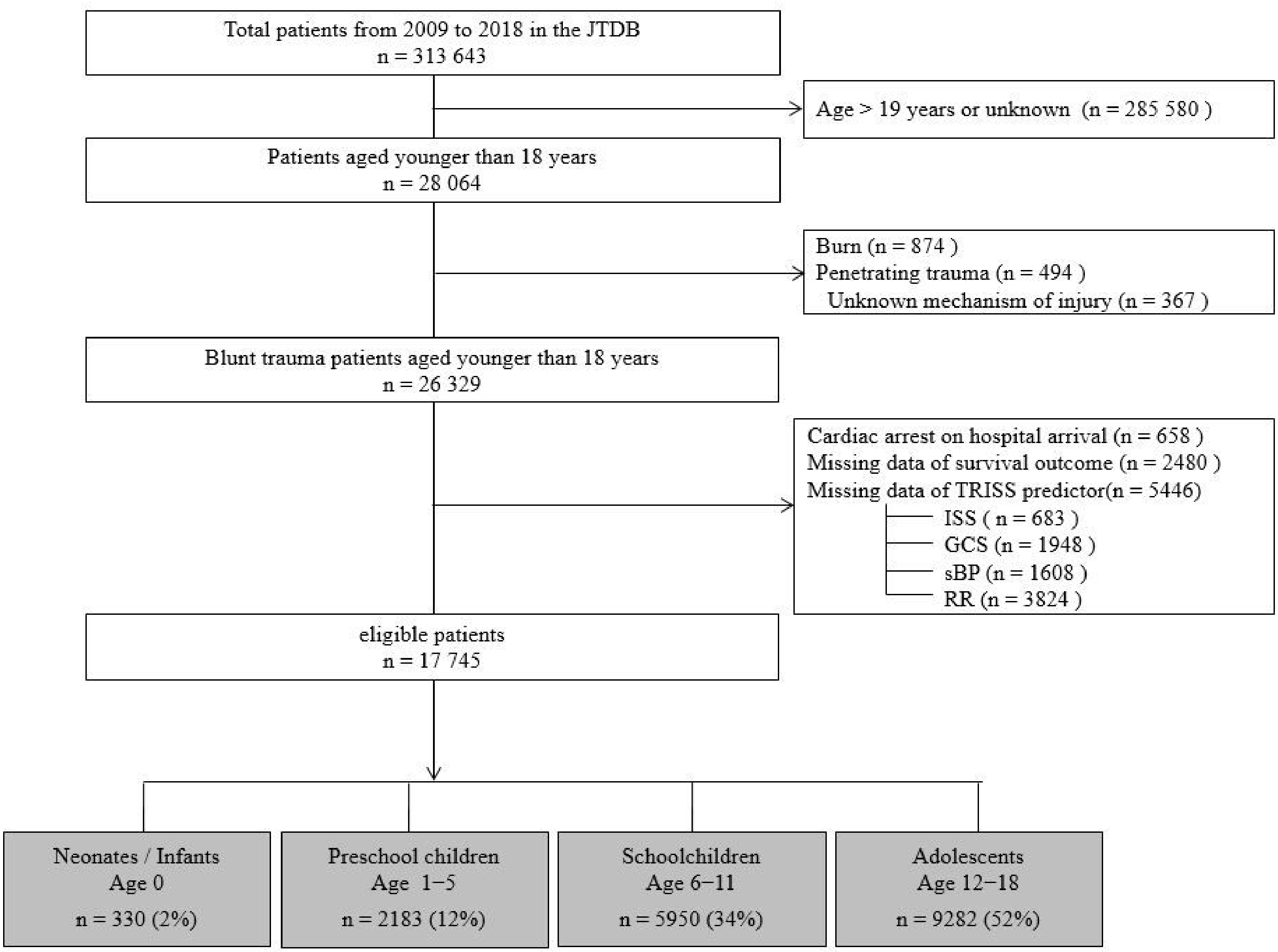

Figure 1

Flow diagram of the study patients' disposition.

Supplementary Files

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- Supplement.xlsx
- Table123.xlsx