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DEVELOPMENT AND VALIDATION OF A PREDICTIVE MODEL FOR CHILDHOOD MORTALITY AFTER A TRAUMATIC BRAIN INJURY: ANALYSIS OF THE NATIONAL TRAUMA DATA BANK

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Introduction

TBI is a significant cause of mortality in the pediatric age group. Patients who receive early, evidence-based interventions show improved recovery process and reduced mortality rate. However, treatment methods tend to vary with patient-level factors. Recent advances in prognostic modeling demonstrate promising capabilities in predicting survival probabilities and patient outcomes from complex, multidimensional clinical data. They are able to process real-time data (i.e., patient demographics, injury characteristics, and clinical parameters) that are routinely available at hospital admission, and thus, have the potential to provide timely accurate prognoses. Thus, creating a dynamic, patient-specific prognostic model would assist clinicians with timely medical decisions, triage patients effectively, and potentially mitigate poor outcomes.

Objectives

- Develop and validate a clinical tool for predicting mortality in children (aged \leq 18 years) with mild to severe TBI.
- Translate our findings into a web-based tool that can be used in clinical practice to calculate and predict the risk of mortality among TBI patients at the time of hospital admission.

Materials and Methods

- This is a predictive study of patient data derived from the National Trauma Data Bank (NTDB) from 2007 to 2015.
- This study adhered to the guidelines set by the Transparent Reporting of a Multivariable Prediction Model for Individual Prognosis or Diagnosis.
- We selected all children (≤18 years) who incurred a traumatic brain injury (TBI), defined according to ICD9 code in the NTDB. We excluded patients with unreported age and those that died on transport or once admitted to the emergency department (ED).
- The primary outcome was in-hospital death. The clinical variables of interest included patient age, gender, race, ethnicity, vitals in the ED, and intent. We also incorporated mode of transportation, time to hospital arrival from 911 call, ED vitals, and ED Glasgow coma scale (GCS), injury type, and mechanism.
- We tabulated descriptive statistics of all patients, and separated by • survivors and non-survivors. Continuous variables were presented as median with interquartile range (IQR) and analyzed by Wilcoxon ranksum test. Categorical data were reported as number with percent and analyzed by the Chi-square test.
- A p-value <5% denoted statistical significance. All analyses were performed with R version 4.0.2.
- We used predictive mean matching and simple bootstrapping methods to impute numeric, categorical, and continuous variables.
- Samples were randomly split into a training set (70%) and a test set (30%).
- In the test set, we measured the prediction performance by computing • the C-statistic (e.g., area under the receiver operating characteristic [ROC] curve), accuracy, sensitivity, specificity, and precision. Furthermore, we conducted a decision curve analysis to assess the net benefit of our prediction models over prediction probability of the reference model. Dynamic nomogram was created in Rshiny

Results

- A total of 124,078 children were included in the study (69% male; median [IQR] age, 13.0 [6.0, 16.0.] years; 69% White), 5.5% (n=6,862) of whom died.
- Those who died were older (16 vs. 12 years, p<5%), arrived faster to the ER (69 vs. 52 minutes, p<5%), had a lower GCS (15 vs. 3, p<5%), and higher ISS (30 vs. 14, p<5%) compared to the survivors.
- Unintentional injuries were the most common among both the survivors and non-survivors (94% vs. 80%, respectively, p<5%).
- The final model had 13 variables that performed well with a high discriminative performance (C-statistic of 95.7%; 95% CI, 95.4% -96.0%) and accuracy of 95.2%.
- strong agreement between the predicted and observed number of events A dynamic nomogram of the validated logistic model was developed as a translational tool for healthcare providers to use in clinical settings.
- The prognostic model reached a precise calibration curve suggesting a





Figure 2. Calibration plot for the TBI model based on admission characteristics.

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Results

Figure 1. Prediction ability of the logistic regression model.

(A) Receiver operating characteristic curve showing a high discriminative ability with an AUC of 0.957 (95% CI = 0.954 - 0.960).

(B) The prognostic model achieved a high accuracy (95.2%) and specificity (96.1%).

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Figure 3. Online webbased calculator for predicting mortality among patients with TBI

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Protect ending upons 13.0 (6.0, 16.0) 12.0 (6.0, 16.0) 16.0 (9.0, 17.0) <0.016	Patient demographies	(n=124,078)	(n=117,216)	(n=6,862)		
Not (oot) Not (oot) <t< td=""><td></td><td>13.0 (6.0, 16.0)</td><td>12.0 (6.0, 16.0)</td><td>16.0 (9.0, 17.0)</td><td><0.001</td></t<>		13.0 (6.0, 16.0)	12.0 (6.0, 16.0)	16.0 (9.0, 17.0)	<0.001	
Sector 39,061 36,891 2,070 (32%) 0.016 Maie (12%) (22%) (30%) 0.016 Maie (12%) (22%) (30%) (70%) Race/Ethnicity - - - Asian (12%) (2.1%) (1.7%) (1.7%) Black 10,922 15,398 1.524 (1.7%) White (19%) (16%) (19%) (2.1%) Other (16%) (16%) (19%) (2.001) Physiologic measures - - - - ISS 14 (8,21) 14 (8,19) 30 (25,41) - - Physiologic measures - </td <td>Sex</td> <td>13.0 (0.0, 10.0)</td> <td>12.0 (0.0, 10.0)</td> <td>10.0 (3.0, 17.0)</td> <td><0.001</td>	Sex	13.0 (0.0, 10.0)	12.0 (0.0, 10.0)	10.0 (3.0, 17.0)	<0.001	
Perman(12%)(32%)(33%)(0.16)Male(05%)(00%)(00%)(00%)(00%)Race/Enholity2.5342.417117Asian(2%)(2.1%)(1.7%)(1.7%)Black(16%)(13%)(22%)(0.0%)White(05%)(06%)(06%)(06%)(06%)(06%)(10%)(00%)(01%)Other19.36718.3061.061Other19.36718.3061.061Pysiologic measure122 (110.139112 (10.133114 (8.140)SBP (mr hg)192 (110.33)122 (110.139114 (8.140)<0.001		39,061	36,991	2,070		
Maie85.017 (70%)80.25 (70%)4.72 (70%)Racé Ethnicity10%10%10%Aaian2.5342.41711.77 	Female	(12%)	(32%)	(30%)	0.016	
(08%) (08%) (08%) (08%) (08%) (08%) (08%) (08%) Race/Ethnoly (2%) (2.1%) (1.7%) (1.7%) (1.7%) Black (14%) (13%) (2.8%) (2.9%) (2.9%) White (16%) (16%) (16%) (2.9%) (2.9%) Other (19%) (16%) (16%) (16%) (2.9%) Other 119,077 18,008 1,010 (10,01) (2.001) SBP (mr Hg) 122 (110,130 112 (110,130 112 (110,130 110 (0.20) <0.001	Male	85,017	80,225	4,792		
ReceilmantyImage: constraint of the section of the sect	Maio	(69%)	(68%)	(70%)		
Asian2.5342.417117117Black10.92215.3981.584(14%)(13%)(22%)White(69%)(69%)(61%)Othe19.96718.3061.061(16%)116%)(16%)(16%)Physiologic measures112 (10.158)30 (25.41)<0.001	Race/Ethnicity					
(2%) (2.1%) (1.7%) <td>Asian</td> <td>2,534</td> <td>2,417</td> <td>117</td> <td></td>	Asian	2,534	2,417	117		
Black(10,32) (14%)(13%) (1%)(.5.44) (22%) (2%)001White88,25581,095(.16%)Other(19%)18,306(.10%)Other(19,367)18,3061.0.01Physiologic measures(.16%)30 (25, 41)<0.011		(2%)	(2.1%)	(1.7%)		
(0.10%) (0.80%) <t< td=""><td>Black</td><td>(14%)</td><td>(13%)</td><td>(22%)</td><td><0.001</td></t<>	Black	(14%)	(13%)	(22%)	<0.001	
White Litto (B9%) Litto (B9%) Litto (B9%) Litto (B9%) Other 19.367 18.306 1.081 Physiologic measures (16%) (16%) (15%) SS 14 (9, 21) 14 (9, 19) 30 (25, 41) <0001		85.255	81.095	4,160	0.001	
Other 19.367 18.306 1.010 Other 19.367 18.306 1.051 Physiologic measures (16%) (16%) 30.25.41) <0.011	White	(69%)	(69%)	(61%)		
Other(16%)(16%)(15%)Physicogic measures14 (9, 21)14 (9, 12)3 (3, 3)<0.001		19,367	18,306	1,061		
Physiologic measures	Other	(16%)	(16%)	(15%)		
Image: bit is the second sec	Physiologic measures					
GCS15 (10, 15)17 (2, 15)3 (3, 3)-0.001SBP (nm hg)122 (110, 135)114 (89, 140)<0.001	ISS	14 (9, 21)	14 (9, 19)	30 (25, 41)	<0.001	
SPP (nm Hg)122 (110, 135)114 (89, 140)<0.001Pulse (bpm)99 (93, 116)99 (83, 116)100 (78, 134)<0.001Respiratory rate20 (16, 24)100 (98, 100)99 (94, 100)<0.001Corps saturation (%)97.88 (96.80)99.860)99.80 (90.80)99.80 (90.80)<0.001Temperature (F)97.88 (96.80)99.860)99.80 (90.80)99.80 (90.80)99.90 (90.97.80)<0.001RAG98.60)99.80 (90.80)99.80 (90.80)99.80 (90.80)99.80 (90.80)<0.001Assisted Respiratory103.924101.5142.410Unassisted Respiratory103.924101.5142.410Rate6.7535.795958Assault6.7535.795958Gel-inflicted(6.753)(0.3%)(0.3%)(3.8%)Uninentional115.858110.3365.522Undetermined/Other828708120Public Building8.0817.929152Recreation16.82111.48%(14%)Public Building8.0817.929152Residential Institution7.929152 </td <td>GCS</td> <td>15 (10, 15)</td> <td>15 (12, 15)</td> <td>3 (3, 3)</td> <td><0.001</td>	GCS	15 (10, 15)	15 (12, 15)	3 (3, 3)	<0.001	
Putse (tpm) 99 (83, 116) 99 (83, 115) 107 (78, 134) <0.001 Respiratory rate 20 (16, 24) 16 (0, 20) <0.001 Charge staturation (%) 100 (98, 100) 100 (98, 100) 99 (94, 100) <0.001 Temperature (-F) 97.88 (96, 80, 98, 80, 95, 97.88) 96.80 (95, 97.88) <0.001 RAQ Assisted Respiratory Rate 20, 154 15, 702 4.452 Importance (-F) 97.88 (96, 80, 97.89) 96.80) (6.5%) <-0.001 Assisted Respiratory Rate 20, 154 (15, 702 4.452 <-0.001 Importance (-F) 88.60) (6.753 5, 755 958 <-0.001 Assault 6, 753 5, 775 958 <-0.001 Seff-inflicted 639 377 262 <-0.001 Undetermined/Other 828 708 120 <-0.001 Industry 352 31,255 1,680 <-0.011 <	SBP (mm Hg)	122 (110, 135)	122 (110, 135)	114 (89, 140)	<0.001	
Respiratory rate 20 (16, 24) 16 (0, 20) -0.001 Oxygen saturation (%) 100 (98, 100) 99 (94, 100) -0.001 Temperature (-F) 97.88 (96.80, 98.60) 96.80 (55.97.88) <0.001	Pulse (bpm)	99 (83, 116)	99 (83, 115)	107 (78, 134)	<0.001	
Crygen seutration (x) Iou (ye, 10u) 10u (ye, 10u) 99 (94, 10u) 90 (00) Temperature (-F) 97.88 (68.09, 98.60) 96.80 (95, 97.88) <0.001 RRAQ - - - - Assisted Respiratory Rate 20, 154 15, 702 4,452 - - Unassisted Respiratory Rate 20, 154 (13%) (65%) - - Unassisted Respiratory Rate 6, 753 5, 795 958 - - Assault 6, 753 5, 795 958 - - - Assault 6, 753 5, 795 958 - - - Giggg 377 262 - - - - - Unintentional 115,858 110,336 5,522 - - - - Locatio - - - - - - - Farm 1,325 1,276 49 - - - - - <td>Respiratory rate</td> <td>20 (16, 24)</td> <td>20 (16, 24)</td> <td>16 (0, 20)</td> <td>< 0.001</td>	Respiratory rate	20 (16, 24)	20 (16, 24)	16 (0, 20)	< 0.001	
Temperature (-F) 98.80) 98.80, 98.80, 98.80, 98.80, 96.97.88) <0.001 RRAQ <0.001 Resisted Respiratory Rate 20.154 15.702 4.452 <0.001 Unassisted Respiratory Rate 103.924 101.514 2.410 <0.001 Important (48%) (87%) (35%) <0.001 Important (48%) (6.753 5.795 958 <0.001 Assault 6.753 5.795 958 <0.38%) <0.014 Assault 6.753 5.795 958 <0.38%) <0.014 Self-inflicted 639 377 262 <0.011 Unintentional 115.858 110.336 5.522 <0.011 Undetermined/Other 828 708 120 <0.011 Home 32.935 31.255 1.680 <0.02%) <0.011 Industry 352 341 11 <0.3%) <0.2% <0.011 Public Building 6.801 0.3%	Oxygen saturation (%)	97,88 (96,80	97,88 (96 98	99 (94, 100)	<0.001	
RRAQ(nmm(nmmm)(nmmm)Asisted Respiratory Rate20,15415,7024,452(16%)(13%)(65%)(65%)(13%)(64%)(87%)(35%)Intert(10,5142,410Intert(5,4%)(4,9%)Assault6,7535,795958(6,5%)(1,4%)(14%)Self-inflicted6393,77262(0,5%)(0,3%)(3,8%)(3,8%)Unintentional(115,658110,3365,522(0,7%)(0,6%)(11%)(0,7%)Unintentional(0,7%)(0,6%)(11%)(0,7%)(0,6%)(11%)(0,7%)Home22,83531,2551,680(1,1%)(1,1%)(0,7%)(24%)Home32,93531,2551,680(0,3%)(0,3%)(0,2%)(0,2%)Industry35234111(0,3%)(0,3%)(0,2%)Necreation(14%)(14%)(14%)(14%)(4.9%)Necreation(14%)(14%)(14%)(14%)(14%)Other57,74053,408(3,0%)(5,5%)(5,5%)Mark(27%)(55%)Mark(1,2%)(1,5%)Other76,50672,7563,750(62%)(62%)(65%)(65%)Pilce75,60672,7563,750(62%)(24%)(11%)Pilce75,58514 <td>Temperature (°F)</td> <td>98.60)</td> <td>98.60)</td> <td>96.80 (95, 97.88)</td> <td><0.001</td>	Temperature (°F)	98.60)	98.60)	96.80 (95, 97.88)	<0.001	
Assisted Respiratory Rate 20,154 (16%) 15,702 (13%) 4,452 (65%) Unassisted Respiratory Rate 103,924 (84%) (13%) (65%) <0.001	RRAQ					
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Dnassisted Respiratory Rate 103,924 (84%) 101,914 (97%) 2,410 (35%) Intent	Rate	(16%)	(13%)	(65%)	<0.001	
Injury characteristics (0,7%) (0,7%) (0,7%) (0,7%) (0,7%) (0,5%) (0,5%) (0,5%) (0,5%) (0,5%) (0,3%) (14%) (0,6%) (0,5%) (0,3%) (14%) (0,0%)	Unassisted Respiratory Rate	103,924	101,514	2,410		
Intent 6,753 5,795 958 Assault 6,753 5,795 958 Self-inflicted 639 377 262 (0.5%) (0.3%) (3.8%) (3.8%) Unintentional 115,858 110,336 5,522 (93%) (94%) (80%) (1.7%) Undetermined/Other 828 708 120 (0.7%) (0.6%) (1.7%) (0.7%) Location	Injury characteristics	(0478)	(07 78)	(3378)		
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Self-inflicted 639 377 262	Assault	(5.4%)	(4.9%)	(14%)		
(0.5%) $(0.3%)$ $(3.8%)$ < 0.01 Unintentional115,858110,3365,522 $(0.3%)$ $(04%)$ $(80%)$ Undetermined/Other828708120 $(0.7%)$ $(0.6%)$ $(1.7%)$ Location-Farm1,3251,276 $(1,1%)$ $(1.1%)$ $(0.7%)$ Home32,93531,255 $(1,03%)$ $(0.2%)$ $(0.3%)$ $(0.2%)$ $(0.3%)$ $(0.2%)$ $(0.3%)$ $(0.2%)$ $(0.3%)$ $(0.2%)$ $(0.3%)$ $(0.2%)$ $(0.3%)$ $(0.2%)$ $(0.3%)$ $(0.2%)$ $(0.3%)$ $(0.2%)$ $(0.3%)$ $(0.2%)$ $(0.3%)$ $(0.2%)$ $(0.3%)$ $(0.2%)$ $(0.3%)$ $(0.2%)$ $(0.3%)$ $(0.2%)$ $(14%)$ $(14%)$ $(14%)$ $(14%)$ $(14%)$ $(14%)$ $(0.3%)$ $(0.3%)$ $(0.3%)$ $(0.2%)$ $(0.1%)$ $(1.1%)$ $(14%)$ $(14%)$ $(14%)$ $(14%)$ $(14%)$ $(14%)$ $(14%)$ $(14%)$ $(11%)$ $(1.1%)$ $(11%)$ $(1.2%)$ $(11%)$ $(1.2%)$ $(11%)$ $(1.2%)$ $(14%)$ $(1.4%)$ $(14%)$ $(1.4%)$ $(14%)$ $(1.4%)$ $(14%)$ $(1.4%)$ $(14%)$ $(1.4%)$ $(14%)$ $(1.4%)$ $(11%)$ $(1.5%)$ $(14%)$	Self-inflicted	639	377	262		
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(85%) (84%) (80%) Undetermined/Other 828 708 120 (0.7%) (0.6%) (1.7%) Location	Unintentional	115,858	110,336	5,522		
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Location Image: Constraint of the second seco	Undetermined/Other	(0.7%)	(0.6%)	(1.7%)		
Farm 1,325 1,276 49 Home 32,935 31,255 1,680 Home 32,935 31,255 1,680 Industry 352 341 11 Public Building 8,081 7,929 152 (6.5%) (6.8%) (2.2%) <0.001	Location	(****)	(*****)			
Interm (1.1%) (1.1%) (0.7%) Home 32,935 31,255 1,680 (27%) (27%) (24%) Industry 352 341 11 (0.3%) (0.3%) (0.2%) Public Building 8,081 7,929 152 Recreation 16,821 16,495 326 (14%) (14%) (4.8%) (0.2%) Residential Institution 396 384 12 (0.3%) (0.3%) (0.2%) (0.2%) Street 57,740 53,408 4,332 (47%) (46%) (63%) (0.2%) Other 6,428 6,128 300 (5.2%) (5.2%) (44%) (4.4%) Transportation Mode 76,506 72,756 3,750 Ground Ambulance (62%) (62%) (55%) Helicopter 31,006 28,161 2,845 (0.4%) (0.4%) (0.6%) (0.6%)	Farm	1,325	1,276	49		
Home32,93531,2551,680 (27%) (27%) (24%) Industry35234111 (0.3%) (0.3%) (0.2%) Public Building (6.5%) (6.8%) (2.2%) (6.5%) (6.8%) (2.2%) (14%) Recreation16,82116,495326 (14%) (14%) (4.8%) (0.3%) Residential Institution39638412 (0.3%) (0.3%) (0.2%) (0.2%) Street57,74053,4084,332 (47%) (46%) (63%) Other $6,428$ $6,128$ 300 (5.2%) (5.2%) (4.4%) Transportation Mode76,50672,7563,750Ground Ambulance $76,506$ 72,7563,750 (62%) (62%) (55%) (41%) Police31,00628,1612,845 (25%) (24%) (41%) Police13,67813,576102 $Private/Public$ 13,67813,576102 (11%) (12%) (1.3%) (1.3%) $Private/Public$ 1,5481,46088 (1.2%) (0.6%) (0.5%) (1.3%) (0.6%) (0.6%) (0.5%) (0.5%) (0.6%) (0.6%) (0.5%) (0.5%) (12%) (0.6%) (0.5%) (0.5%) (0.6%) (0.6%) (0.5%) (0.5%) (12%) (0.6%) (0.6%) <		(1.1%)	(1.1%)	(0.7%)		
$ \begin{array}{ c c c c c c } \hline (27\%) & (27\%) & (24\%) \\ \hline (27\%) & (27\%) & (24\%) \\ \hline (27\%) & (27\%) & (24\%) \\ \hline (1000 \ S52 & 341 & 11 \\ (0.3\%) & (0.3\%) & (0.2\%) \\ \hline (0.3\%) & (0.3\%) & (0.2\%) \\ \hline (0.5\%) & (6.8\%) & (2.2\%) \\ \hline (6.5\%) & (6.8\%) & (2.2\%) \\ \hline (14\%) & (14\%) & (4.8\%) \\ \hline (14\%) & (14\%) & (4.8\%) \\ \hline (14\%) & (14\%) & (4.8\%) \\ \hline (0.3\%) & (0.3\%) & (0.2\%) \\ \hline (0.3\%) & (0.3\%) & (0.2\%) \\ \hline (0.3\%) & (0.3\%) & (0.2\%) \\ \hline (14\%) & (46\%) & (63\%) \\ \hline (14\%) & (14\%) & (63\%) \\ \hline (14\%) & (12\%) & (1.5\%) \\ \hline (11\%) & (12\%) & (1.5\%) \\ \hline (11\%) & (12\%) & (1.3\%) \\ \hline (11\%) & (16\%) & (1.3\%) \\ \hline (11\%) & (16\%) & (1.3\%) \\ \hline (11\%) & (16\%) & (1.3\%) \\ \hline (11\%) & (12\%) & (1.3\%) \\ \hline (11\%) & (16\%) & (1.3\%) \\ \hline (11\%) & (12\%) & (1.3\%) \\ \hline (11\%) & (16\%) & (1.3\%) \\ \hline (11\%) & (0.6\%) & (0.5\%) \\ \hline (11\%) & (11\%) & (11\%) & (11\%) \\ \hline (11\%) & (11\%) & (11\%) \\ \hline (11\%) & (11\%) & (11\%) & (11\%) \\ \hline (11\%) & (11\%) & (11\%) & (11\%) \\ \hline (11\%) & (11\%) & (11\%) & (11\%) \\$	Home	32,935	31,255	1,680		
$ \begin{array}{ c c c c c } \mbox{Industry} & 352 & 341 & 11 \\ \hline 0.3\% & (0.3\%) & (0.2\%) \\ \hline 0.1\% & 8,081 & 7,929 & 152 \\ \hline 0.6.5\% & (6.8\%) & (2.2\%) \\ \hline 0.1\% & (6.8\%) & (2.2\%) \\ \hline 0.1\% & (14\%) & (14\%) & (4.8\%) \\ \hline 0.1\% & (14\%) & (14\%) & (4.8\%) \\ \hline 0.3\% & (0.3\%) & (0.2\%) \\ \hline 0.3\% & (47\%) & (46\%) & (63\%) \\ \hline 0.1\% & (46\%) & (63\%) \\ \hline 0.1\% & (5.2\%) & (5.2\%) & (4.4\%) \\ \hline 1 \mbox{Industrian} & 1 \ 0.5(2\%) & (5.2\%) & (4.4\%) \\ \hline 1 \ 1 \ 0.5(2\%) & (5.2\%) & (4.4\%) \\ \hline 1 \ 1 \ 0.5(2\%) & (5.2\%) & (4.4\%) \\ \hline 1 \ 1 \ 0.5(2\%) & (5.2\%) & (5.2\%) & (4.4\%) \\ \hline 1 \ 1 \ 0.5(2\%) & (62\%) & (55\%) & (62\%) & (55\%) \\ \hline 1 \ 0 \ 1 \ 0.5(2\%) & (24\%) & (11\%) & (12\%) & (15\%) \\ \hline 1 \ 1 \ 0.1(2\%) & (1.5\%) & (1.2\%) & (1.5\%)$		(27%)	(27%)	(24%)		
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	Industry	352	341	11		
Public Building 1.1.1 1.1.2		8.081	7.929	152		
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	Public Building	(6.5%)	(6.8%)	(2.2%)	<0.001	
Recreation (14%) (14%) (4.8%) Residential Institution 396 384 12 (0.3%) (0.3%) (0.2%) Street 57,740 53,408 4,332 (47%) (46%) (63%) Other 6,428 6,128 300 (5.2%) (5.2%) (4.4%) (4.4%) Transportation Mode		16,821	16,495	326		
$ \begin{array}{ c c c c c c } \hline Residential Institution & 396 & 384 & 12 \\ (0.3\%) & (0.3\%) & (0.2\%) \\ \hline \\ \hline Residential Institution & \\ \hline \\ \hline \\ Street & 57,740 & 53,408 & 4,332 \\ (47\%) & (46\%) & (63\%) \\ \hline \\ \hline \\ Other & 6,428 & 6,128 & 300 \\ (5.2\%) & (5.2\%) & (4.4\%) \\ \hline \\ \hline \\ \hline \\ Transportation Mode & & \\ \hline \\ \hline \\ Ground Ambulance & 76,506 & 72,756 & 3,750 \\ (62\%) & (62\%) & (55\%) \\ \hline \\ Helicopter & 31,006 & 28,161 & 2,845 \\ (25\%) & (24\%) & (41\%) \\ \hline \\ Police & 558 & 514 & 44 \\ (0.4\%) & (0.4\%) & (0.6\%) \\ \hline \\ Private/Public & 13,678 & 13,576 & 102 \\ (11\%) & (12\%) & (1.5\%) \\ \hline \\ \hline \\ \hline \\ Fixed-wing Ambulance & 1,548 & 1,460 & 88 \\ (1.2\%) & (1.2\%) & (1.3\%) \\ \hline \\ \hline \\ Other & 782 & 749 & 33 \\ (0.6\%) & (0.6\%) & (0.5\%) \\ \hline \\ $	Recreation	(14%)	(14%)	(4.8%)		
Instrument (0.3%) (0.3%) (0.2%) Street 57,740 53,408 4,332 (47%) (46%) (63%) Other 6,428 6,128 300 (5.2%) (5.2%) (4.4%) Transportation Mode	Residential Institution	396	384	12		
$ \begin{array}{ c c c c } Street & 57,740 & 53,408 & 4,332 \\ \hline & (47\%) & (46\%) & (63\%) \\ \hline & (47\%) & (46\%) & (63\%) \\ \hline \\ \hline \\ \hline \\ Other & 6,428 & 6,128 & 300 \\ \hline & (5.2\%) & (5.2\%) & (4.4\%) \\ \hline \\ \hline \\ \hline \\ Transportation Mode & & & & & & & \\ \hline \\ \hline \\ Transportation Mode & & & & & & & \\ \hline \\ \hline \\ Transportation Mode & & & & & & & & \\ \hline \\ \hline \\ \hline \\ Ground Ambulance & 76,506 & 72,756 & 3,750 \\ \hline & (62\%) & (62\%) & (55\%) & & & & \\ \hline \\ \hline \\ \hline \\ \hline \\ \\ \hline \\ \hline \\ Helicopter & & 31,006 & 28,161 & 2,845 \\ \hline & (25\%) & (24\%) & (41\%) & & & \\ \hline \\ \hline \\ \hline \\ \hline \\ Police & & & & & & & & & \\ \hline \\ \hline \\ Police & & & & & & & & & & \\ \hline \\ \hline \\ Police & & & & & & & & & & & \\ \hline \\ \hline \\ Police & & & & & & & & & & & & \\ \hline \\ \hline \\ Police & & & & & & & & & & & & & & & \\ \hline \\ Police & & & & & & & & & & & & & & & & \\ \hline \\ Police & & & & & & & & & & & & & & & & & & \\ \hline \\ Police & & & & & & & & & & & & & & & & & & &$		(0.3%)	(0.3%)	(0.2%)		
$ \begin{array}{ c c c c } \hline (47\%) & (46\%) & (63\%) \\ \hline (47\%) & (46\%) & (63\%) \\ \hline \\ $	Street	57,740	53,408	4,332		
$\begin{tabular}{ c c c c } \hline $6,428$ & $6,128$ & 300 \\ \hline (5.2%) & (5.2%) & (4.4%) \\ \hline (5.2%) & (5.2%) & (4.4%) \\ \hline (5.2%) & (5.2%) & (5.2%) & (5.2%) & (5.2%) & (5.2%) & (62%) & (62%) & (55%) & (62%) & (62%) & (55%) & (62%) & (62%) & (55%) & (62%) & (62%) & (55%) & (55%) & (62%) & (62%) & (55%) & (62%) & (62%) & (55%) & (62%) &$		(47%)	(46%)	(63%)		
$\begin{tabular}{ c c c c c } \hline (5.2\%) & (5.2\%) & (4.4\%) \\ \hline (5.2%) & (5.2\%) & (5.2\%) & (5.2\%) & (5.2\%) & (5.2\%) & (5.2\%) & (62\%) & (62\%) & (55\%) & (62\%) & (62\%) & (55\%) & (62\%) & (62\%) & (55\%) & (62\%) & (24\%) & (41\%) & (25\%) & (24\%) & (41\%) & (25\%) & (24\%) & (41\%) & (25\%) & (25\%) & (24\%) & (41\%) & (0.6\%) & (0.6\%) & (0.6\%) & (0.6\%) & (0.6\%) & (0.6\%) & (0.6\%) & (1.5\%) & (1.2\%) & (1.2\%) & (1.5\%) & (1.2\%) & (1.2\%) & (1.3\%) & (1.2\%) & (1.2\%) & (1.3\%) & (0.6\%) & (0.6\%) & (0.6\%) & (0.5\%) & \hline \end{tabular}$	Other	6,428	6,128	300		
Anterportation induce 76,506 72,756 3,750 Ground Ambulance 76,506 (62%) (55%) Helicopter 31,006 28,161 2,845 (25%) (24%) (41%) Police 558 514 44 (0.4%) (0.4%) (0.6%) Private/Public 13,678 13,576 102 (11%) (12%) (1.5%) (1.5%) Fixed-wing Ambulance 1,548 1,460 88 (1.2%) (1.2%) (1.3%) (0.6%) Other 782 749 33 (0.6%) (0.6%) (0.5%) <<0.001	Transportation Mode	(5.2%)	(5.2%)	(4.4%)		
Ground Ambulance 10,100 11,100 0,001 0,001 <td>Transportation Mode</td> <td>76,506</td> <td>72,756</td> <td>3.750</td> <td></td>	Transportation Mode	76,506	72,756	3.750		
Helicopter 31,006 28,161 2,845 (25%) (24%) (41%) Police 558 514 44 (0.4%) (0.4%) (0.6%) (15%) Private/Public 13,678 13,576 102 (11%) (12%) (1.5%) (1.5%) Fixed-wing Ambulance 1,548 1,460 88 (1.2%) (1.2%) (1.3%) (0.6%) Other 782 749 33 (0.6%) (0.6%) (0.5%) EMS Minutes 68 (42, 183) 69 (42, 195) 52 (32, 92) <0.001	Ground Ambulance	(62%)	(62%)	(55%)		
Itelicopter (25%) (24%) (41%) Police 558 514 44 (0.4%) (0.4%) (0.6%) (0.6%) Private/Public 13,678 13,576 102 (11%) (12%) (1.5%) (1.5%) Fixed-wing Ambulance 1,548 1,460 88 (1.2%) (1.2%) (1.3%) (1.3%) Other 782 749 33 (0.6%) (0.6%) (0.5%) (0.5%) EMS Minutes 68 (42, 183) 69 (42, 195) 52 (32, 92) <0.001	Holiooptor	31,006	28,161	2,845		
Police 558 514 44 (0.4%) (0.4%) (0.6%) Private/Public 13,678 13,576 102 (11%) (12%) (1.5%) 1.5% Fixed-wing Ambulance 1,548 1,460 88 (1.2%) (1.2%) (1.3%) Other 782 749 33 (0.6%) (0.6%) (0.5%) EMS Minutes 68 (42, 183) 69 (42, 195) 52 (32, 92) <0.001	Helicopter	(25%)	(24%)	(41%)		
(0.4%) (0.4%) (0.6%) <0.001 Private/Public 13,678 13,576 102 (11%) (12%) (1.5%) Fixed-wing Ambulance 1,548 1,460 88 (1.2%) (1.2%) (1.3%) Other 782 749 33 (0.6%) (0.6%) (0.5%) EMS Minutes 68 (42, 183) 69 (42, 195) 52 (32, 92) <0.001	Police	558	514	44		
Private/Public 13,678 13,576 102 (11%) (12%) (1.5%) Fixed-wing Ambulance 1,548 1,460 88 (1.2%) (1.2%) (1.3%) Other 782 749 33 (0.6%) (0.6%) (0.5%) EMS Minutes 68 (42, 183) 69 (42, 195) 52 (32, 92) <0.001		(0.4%)	(0.4%)	(0.6%)	<0.001	
$ \begin{array}{ c c c c c c c c } \hline & (11\%) & (12\%) & (1.5\%) \\ \hline & (11\%) & (12\%) & (1.5\%) \\ \hline & 1,548 & 1,460 & 88 \\ \hline & (1.2\%) & (1.2\%) & (1.3\%) \\ \hline & 0 \\ \hline & 0 \\ \hline & 0 \\ \hline & 0 \\ \hline \\$	Private/Public	13,678	13,576	102		
Fixed-wing Ambulance 1,345 1,400 88 (1.2%) (1.2%) (1.3%) Other 782 749 33 (0.6%) (0.6%) (0.5%) (0.5%) EMS Minutes 68 (42, 183) 69 (42, 195) 52 (32, 92) <0.001		(11%)	(12%)	(1.5%)		
Other 782 (0.6%) 749 (0.6%) 33 (0.6%) EMS Minutes 68 (42, 183) 69 (42, 195) 52 (32, 92) <0.001	Fixed-wing Ambulance	(1.2%)	(1.2%)	(1.3%)		
Other 0.6% (0.6%) (0.5%) EMS Minutes 68 (42, 183) 69 (42, 195) 52 (32, 92) <0.001		782	749	33		
EMS Minutes 68 (42, 183) 69 (42, 195) 52 (32, 92) <0.001	Other	(0.6%)	(0.6%)	(0.5%)		
	EMS Minutes	68 (42, 183)	69 (42, 195)	52 (32, 92)	<0.001	

 Table 1. Multivariable
 Regression Analysis of Characteristics of Children with TBI, 2007-2015, by survival status

GCS-Glasgow coma scale; ISS-injury severity score; SBP-systolic blood pressure; RRAQ-respiratory rate qualifier: assessment Continuous variables expressed as (median, IQR); Categorical variables expressed as n (%); Statistical test performed: Wilcoxon ranksum test (continuous), Chi-square (categorical)

Conclusion

- Our results indicate several independent early factors significant in predicting mortality in children with mild to severe TBI
- We provide an accurate early prognostic model with high discriminative ability, accuracy, specificity, and calibration to measure the risk of mortality among children with mild to severe TBI.
- Our findings have led to a clinically translatable web-based tool to potentially provide a timely estimation of the risk of mortality among pediatric patients with TBI admitted to the ED.
- To our knowledge, this study is the largest study that uses a mathematical model to identify early predictors of mortality in children with mild to severe TBI and to develop a tool that can be easily used clinically.
- Future directions: externally validate the data and compare our model to other trauma scores used in children