

# Assessment of Blood Consumption score for pediatrics (ped-ABC score) predicts transfusion requirements for children with trauma.

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## Original research

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# Abstract

## Background

Although transfusion is one of primary life-saving elements, the assessment of requirement for transfusion in children with trauma at an early phase has been challenging. We aimed to develop a scoring system for predicting transfusion requirements in children with trauma.

## Methods

This is a retrospective cohort study, which employed a nationwide registry of patients with trauma (Japan Trauma Data Bank) and included the patients aged < 16 years with blunt trauma between 2004 and 2015. An Assessment of Blood Consumption score for pediatrics (ped-ABC score) was developed based on previous literatures and clinical relevance. One point was assigned for each of the following criteria: systolic blood pressure  $\leq$  90 mmHg; heart rate  $\geq$  120/min; Glasgow Coma Scale (GCS) < 15; and positive result on focused assessment with sonography for trauma (FAST) scan. For sensitivity analysis, we assessed age-adjusted ped-ABC scores using cut-off points for different ages.

## Results

In total, 540 patients had transfusion within 24 hours after trauma among the eligible 5,943 pediatric patients with trauma. The in-hospital mortality rate was 2.6% (145/5,615). Transfusion increased from 7.6% (430/5,631) to 35.3% (110/312) in patients with systolic blood pressure  $\leq$  90 mmHg (1 point); from 6.1% (276/4,504) to 18.3% (264/1,439) for heart rate  $\geq$  120/min (1 point); from 4.1% (130/3,198) to 14.9% (410/2,745) for disturbance of consciousness with GCS < 15 (1 point); and from 7.4% (400/5,380) to 24.9% (140/563) for FAST positivity (1 point). The ped-ABC score of 0, 1, 2, 3, and 4 points were associated with the transfusion rates of 2.2% (48/2,210), 7.5% (198/2,628), 19.8% (181/912), 53.3% (88/165), and 89.3% (25/28), respectively. After age adjustment, c-statistic was 0.76 (95% CI, 0.74–0.78).

## Conclusions

The ped-ABC score using the vital signs and FAST may be helpful in predicting the transfusion requirements within 24 hours for children with trauma.

## Background

Trauma is a leading cause of death among young populations around the world [1, 2]. Even if most of the injuries of children are of mild to moderate severity [3], a rapid evaluation and management for children with serious and life-threatening trauma is always needed to avoid preventable trauma death.

Transfusion is one of key life-saving elements for children with trauma. Delay in transfusion is primarily associated with increased mortality [4, 5]. However, it has been challenging for a clinician to assess the requirements for transfusion among children with trauma at an early phase [6]. In addition, clinicians may hesitate to use transfusion for children due to the risks of transfusion-related complications such as infection or allergic reaction [7].

Several transfusion prediction scoring systems are available for the patients with trauma [8, 9]. Majority of these systems were developed for adults and, subsequently, applied to pediatric populations; however, their effectiveness may be limited for children [10]. Indeed, most transfusions for pediatric patients with trauma were decided without clear indications [11]. There is no prediction scoring system focused on blood transfusion in children with trauma.

Therefore, the objective of this study is to develop a scoring system to predict the requirements for transfusion in children with trauma.

## Methods

### Design and data collection

This is a retrospective cohort study, which employed a nationwide registry of trauma patients in Japan: Japan Trauma Data Bank (JTDB). JTDB is a nationwide trauma registry established in 2003, which is authorized and maintained by the Japanese Association for the Surgery of Trauma and the Japanese Association for Acute Medicine to improve and assure the quality of trauma care in Japan. A total of 272 hospitals, including over 95% of certified tertiary emergency medical centers in Japan, contributed to the JTDB in March 2018 [12]. The JTDB collected data regarding patient demographics, trauma cause, Injury Severity Score (ISS), vital signs and emergency procedure at pre-hospital on arrival, and at hospital, and treatment and emergency procedure including transfusion within 24 hours. It also collected outcome data such as emergency department (ED) mortality, in-hospital mortality, and length of stay.

### Patient selection

All patients aged < 16 years of age with blunt trauma were included (Fig. 1). Exclusion criteria were: patients who had missing data of age; patients who had trauma mechanisms other than blunt trauma or patients with missing data of trauma mechanism; patients who had no information about transfusion; patients with cardiorespiratory arrest upon arrival at hospital or patients with an Abbreviated Injury Scale (AIS) score of  $\leq 2$  or 6 (i.e., non-survivable injury) for any reason. We also excluded patients for whom focused assessment with sonography for trauma (FAST) scan was not conducted or data were missing; patients with missing data of systolic blood pressure (SBP), heart rates (HR), and Glasgow Coma Scale (GCS) at ED. Thus, data included in analysis were of those patients who represented the complete datasets for score predictors of SBP, HR, GCS, and FAST.

### Development of prediction score

The Assessment of Blood Consumption score for pediatrics (ped-ABC score) was developed based on the previous literatures and clinical relevance (Table 1). It consists of some components of Assessment of Blood Consumption (ABC) score, which was developed to predict massive transfusion for adult patients with trauma [9], and disturbance of consciousness, which we defined as GCS < 15. We considered how the association between disturbance of consciousness and transfusion is explained through physiological rationale: severe blood loss decreases cerebral blood flow and perfusion, resulting in the disturbance of consciousness [13]. Finally, 1 point was given for each of the following criteria: SBP  $\leq$  90 mmHg; heart rate  $\geq$  120/min; GCS < 15; and positive result on the FAST scan.

Table 1  
Assessment of Blood Consumption score for Pediatrics

Score Item	Scoring
Systolic blood pressure	
$\leq$ 90 mmHg	1
Not applicable to above	0
Heart rate	
$\geq$ 120/min	1
Not applicable to above	0
Consciousness	
< 15 points on Glasgow Coma Scale	1
Normal	0
FAST	
Positive	1
Negative	0
FAST, Focused assessment with sonography for trauma	

## Statistical analysis

Continuous variables were presented as median and interquartile range values. These variables were compared by using the Mann–Whitney *U* test or as mean  $\pm$  standard deviation, which was compared by using t-test as appropriately. Categorical variables were presented as numbers and percentages and compared by using either the Chi-square test or Fisher exact test. Scoring items were assessed by using c-statistic with 95% confidence interval (CI), and the characteristics were evaluated by using sensitivity, specificity, and positive and negative predictive values for the score cut-off values of 1, 2, 3, and 4, respectively. For sensitivity analysis, we also assessed the age-adjusted ped-ABC score by using cut-off points for different age categories because the normal range of vital signs among pediatric populations

differ as per their age [6, 14]. Normal vital signs and cut-off points were based on the published normal ranges compiled from the pediatric textbooks and guidelines [15, 16]. In the age-adjusted ped-ABC score, one point was given for each of the following criteria: SBP  $\leq 70$  mmHg plus child's age multiplied by 2 (age  $\leq 10$  years) or  $\leq 90$  mmHg (age  $> 10$  years); heart rate  $\geq 160$ /min (age  $\leq 1$  years),  $\geq 150$ /min (1  $<$  age  $\leq 2$  years),  $\geq 140$ /min (3  $\leq$  age  $\leq 5$  years),  $\geq 120$ /min (6  $\leq$  age  $\leq 12$  years), or  $\geq 100$ /min (age  $\geq 13$  years); GCS  $< 15$ ; and positive result on the FAST scan.

We also conducted subgroup analyses that only included patients with ISS  $\geq 15$ ; patients without isolated head injury; those without severe isolated head injury (ISS  $\geq 3$  on head score of AIS). Patients with isolated head injury were considered to have received transfusion mainly for surgical operation.

For all analyses, a p-value  $< 0.05$  was considered to be statistically significant. All statistical analyses were performed with EZR (version 1.38; Saitama Medical Center, Jichi Medical University, Saitama, Japan), a graphical user interface for R (version 3.5.0; The R Foundation for Statistical Computing, Vienna, Austria) [17]. More specifically, EZR is a modified version of R commander designed to apply statistical functions frequently used in biostatistics.

## Results

### Clinical characteristics

The JTDB enrolled 236,698 patients between January 2004 and December 2015. Of these, 5,943 pediatric patients with trauma (2.5%) were eligible in our study (Table 2). In total, 540 patients (9.1%) had transfusion within 24 hours after trauma. ISS was higher in the patients who received transfusion than in those patients without transfusion (25 (16–34) vs. 10 (9–17),  $p < 0.01$ ). Patients who received transfusion had higher HR (118 (94–142) vs. 100 (85–116),  $p < 0.01$ ), lower SBP (114 (98–132) vs. 120 (110–132),  $p < 0.01$ ), and lower GCS (10 (6–14) vs. 15 (13–15),  $p < 0.01$ ) as compared to those without transfusion. Positive results of FAST scan were also higher in patients who received transfusion as compared to the patients without transfusion (140 (25.9%) vs. 423 (7.8%),  $p < 0.01$ ). The overall in-hospital mortality rate was 2.6% (145/5,615). The mortality rates of the patients who received transfusion and the patients who did not receive transfusion were 20.2% (100/494) and 0.9% (45/5,121), respectively.

Table 2  
Characteristics of patients

Characteristic	Transfusion (n = 540)	Non-transfusion (n = 5,403)	P-value
Age —yr	8.6 (± 4.6)	9.2 (± 4.0)	< 0.01
Male gender	364 (67.4)	3,773 (69.8)	0.31
Causes of trauma			< 0.01
Traffic accident	350 (64.8)	3,588 (66.4)	
Sports	6 (1.1)	208 (3.8)	
Fall	156 (28.9)	1,437 (26.6)	
Other blunt trauma	28 (5.2)	170 (3.1)	
AIS			
Head (n = 3,627)	4 (3–5)	3 (2–4)	< 0.01
Face (n = 1,482)	2 (1–2)	1 (1–2)	< 0.01
Neck (n = 41)	2 (1–3)	1 (1–1)	0.13
Thorax (n = 1,442)	4 (3–4)	3 (3–4)	< 0.01
Abdomen and Pelvis (n = 1,278)	3 (2–4)	2 (2–3)	< 0.01
Cervical Spine (n = 376)	2 (2–3)	2 (2–3)	0.20
Upper extremity (n = 1,454)	2 (2–3)	2 (1–2)	< 0.01
Lower extremity (n = 1,985)	3 (2–3)	2 (1–3)	< 0.01
Others (n = 407)	1 (1–1)	1 (1–1)	0.31
ISS	25 (16–34)	10 (9–17)	< 0.01
Vital sign at ED			
HR (/min)	118 (94–142)	100 (85–116)	< 0.01
SBP (mmHg)	114 (98–132)	120 (110–132)	< 0.01

Reported counts (proportions) for categorical variables and median (interquartile range) for continuous variables except for age (mean (SD)). Continuous variables were compared using the Mann–Whitney *U* test. Categorical variables were compared using the Fisher's exact test.

Missing data (T+/T-): RR (33/384), Temperature (73/473), RTS (33/384), TRISS (38/429), mortality (46/282), mortality in ED or OR (5/103), discharge disposition (53/308)

AIS, Abbreviated Injury Scale; ISS, Injury Severity Score; HR, Heart rate; SBP, Systolic blood pressure; GCS, Glasgow coma scale; FAST, Focused assessment with sonography for trauma; RTS, Revised trauma score; TRISS, Trauma and injury severity score; ED, emergency department; OR, operation room

Characteristic	Transfusion (n = 540)	Non-transfusion (n = 5,403)	P-value
RR (/min)	26 (20–31)	24 (20–28)	< 0.01
GCS	10 (6–14)	15 (13–15)	< 0.01
Temperature (°C)	36.4 (35.8–36.9)	36.7 (36.2–37.1)	< 0.01
FAST			< 0.01
Positive	140 (25.9)	423 (7.8)	
Negative	400 (74.1)	4980 (92.2)	
RTS	6.6 (5.4–7.6)	7.8 (7.6–7.8)	< 0.01
TRISS	0.94 (0.73–0.98)	0.99 (0.98–0.99)	< 0.01
Mortality (overall)	100 (20.2)	45 (0.9)	< 0.01
Mortality in ED or OR	7 (1.3)	7 (0.1)	
Discharge disposition			< 0.01
Home	244 (63.0)	4183 (82.8)	
Inter-hospital transfer	139 (35.9)	835 (16.5)	
Other	4 (1.0)	32 (0.6)	
Reported counts (proportions) for categorical variables and median (interquartile range) for continuous variables except for age (mean (SD)). Continuous variables were compared using the Mann–Whitney <i>U</i> test. Categorical variables were compared using the Fisher's exact test.			
Missing data (T+/T-): RR (33/384), Temperature (73/473), RTS (33/384), TRISS (38/429), mortality (46/282), mortality in ED or OR (5/103), discharge disposition (53/308)			
AIS, Abbreviated Injury Scale; ISS, Injury Severity Score; HR, Heart rate; SBP, Systolic blood pressure; GCS, Glasgow coma scale; FAST, Focused assessment with sonography for trauma; RTS, Revised trauma score; TRISS, Trauma and injury severity score; ED, emergency department; OR, operation room			

Table 3 shows the distribution of patients by score items. Transfusion increased from 7.6% (430/5,631) to 35.3% (110/312) in those with SBP  $\leq$  90 mmHg (1 point); from 6.1% (276/4,504) to 18.3% (264/1,439) for heart rate  $\geq$  120/min (1 point); from 4.1% (130/3,198) to 14.9% (410/2,745) for disturbance of consciousness with GCS < 15 (1 point); and from 7.4% (400/5,380) to 24.9% (140/563) for FAST positivity (1 point).

Table 3  
Mortality and distribution of patients according to score item

Score item	n (%)	Transfusion (%)	Mortality (%)
Systolic blood pressure			
≤ 90 mmHg or less than 90	312 (5.2)	110 (35.3)	59/297 (19.9)
> 90 mmHg	5,631 (94.8)	430 (7.6)	86/5,318 (1.6)
Heart rate			
≥ 120/min	1,439 (24.2)	264 (18.3)	70/1,359 (5.2)
< 120	4,504 (75.8)	276 (6.1)	75/4,256 (1.8)
Consciousness			
< 15 points on GCS	2,745 (46.2)	410 (14.9)	143/2,588 (5.5)
Normal	3,198 (53.8)	130 (4.1)	2/3,027 (0.1)
FAST			
Positive	563 (9.5)	140 (24.9)	21/536 (3.9)
Negative	5,380 (90.5)	400 (7.4)	124/5,079 (2.4)
FAST, Focused assessment with sonography for trauma; GCS, Glasgow coma scale			

## Ability of ped-ABC score

The transfusion rates of patients in accordance with the ped-ABC score are presented in Table 4. Although the patients with a score of 0 had a transfusion rate of only 2.2%, 89.3% of those with a maximum score of 4 received transfusion. Most patients scored less than 3 (96.7%).

Table 4  
Transfusion of patients according to Assessment of Blood Consumption score for Pediatrics

Score	n (%)	Transfusion by score, n (%)	Cumulative transfusion, n (%)
0	2,210 (37.2)	48 (2.2)	48 (0.8)
1	2,628 (44.2)	198 (7.5)	246 (4.1)
2	912 (15.3)	181 (19.8)	427 (7.2)
3	165 (2.8)	88 (53.3)	515 (8.7)
4	28 (0.5)	25 (89.3)	540 (9.1)

The score characteristics for transfusion rates in accordance with the different cut-offs are presented in Table 5. The specificity of the patients with a score of 1, 2, 3, and 4 were 40.0%, 85.0%, 98.5% and 99.9%,

respectively. Sensitivity was 91.1% for patients with a score of 1, and the negative likelihood ratio for transfusion was 0.22 (95% CI, 0.17–0.29) and negative predict value was 97.8% (95% CI, 97.2–98.3). For patients with a score of 3, the positive likelihood ratio for transfusion and positive predict value were 14.1 (95% CI, 10.8–18.5) and 58.5% (95% CI, 51.9–64.9). In addition, for the patients with a score of 4, the positive likelihood ratio for transfusion and positive predict value were 83.4 (95% CI, 26.9–259.3) and 89.3% (95% CI, 72.9–96.3), respectively. C-statistic of the score was 0.76 (95% CI, 0.74–0.78).

Table 5  
Score characteristics for transfusion by varying score cut-offs

Cut-off of score	Sensitivity (95% CI), %	Specificity (95% CI), %	PPV (95% CI), %	NPV (95% CI), %	LR+ (95% CI)	LR- (95% CI)
≥ 1	91.1 (88.5–93.2)	40.0 (40.0–40.0)	13.2 (12.8–13.5)	97.8 (97.2–98.3)	1.52 (1.47–1.56)	0.22 (0.17–0.29)
≥ 2	54.4 (50.6–58.2)	85.0 (84.6–85.4)	26.6 (24.7–28.5)	94.9 (94.5–95.3)	3.63 (3.29–3.98)	0.54 (0.49–0.58)
≥ 3	20.9 (18.5–23.2)	98.5 (98.3–98.7)	58.5 (51.9–64.9)	92.6 (92.4–92.8)	14.1 (10.8–18.5)	0.80 (0.78–0.83)
4	4.6 (3.8–5.0)	99.9 (99.9–1.00)	89.3 (72.9–96.3)	91.3 (91.2–91.3)	83.4 (26.9–259.3)	0.95 (0.95–0.96)
PPV, Positive predict value; NPV, Negative predict value; LR+, Positive likelihood rate; LR-, Negative likelihood rate						

## Sensitive and subgroup analyses of ped-ABC score

Supplemental Table 1 shows the number of patients and transfusion rate for each age category. After age adjustment by using different cut-off points, c-statistic of the score was 0.76 (95% CI, 0.74–0.78), which was similar to score before adjustment. The specificity of score after age adjustment was higher than the score before adjustment (Supplemental Table 2, 3). The other analysis also showed similar test characteristics with respect to the original score (Supplemental Table 4–9).

## Discussion

### Brief summary

We developed a scoring system to predict the requirements of transfusion for children with trauma by using a nationwide registry of trauma patients in Japan. It includes results of SBP, HR, GCS and FAST scan. It is helpful for clinicians to make a systematic evaluation with this simplified method.

### Development of ped-ABC score

We have developed the ped-ABC score, which consisted of vital signs and FAST. Tachycardia and hypotension as well as decreased GCS were associated with poor outcomes in the pediatric patients with trauma [18–20]. In addition, positive result of FAST strongly suggests intraabdominal injury that is one of the main reasons for the need of transfusion [21, 22]. Scores with multiple combinations of vital signs improve their predictability as compared to the vital signs alone [23].

Indicators that use vital signs tend to be complicated in children because the normal range of vital signs varies with age. In this study, sensitivity analysis performed with age adjustment demonstrated that the test characteristics were equivalent to those before adjustment. Therefore, it is possible to adapt its scoring system more easily in children with trauma without setting different cut-offs for each age. We confirmed that subgroup analyses of patients with ISS  $\geq$  15, patients without isolated head injury, and patients without severe isolated head injury were also equivalent to the original score. Establishing a scoring system also makes it easier for a clinician to assess the requirement for transfusions in a busy ED.

## **Comparison with previous studies**

Previous studies have reported that shock index (SI), which is calculated by the normal heart rate divided by the SBP, predicted mortality among pediatric patients with trauma and served as a requirement for transfusion [24, 25]. The prediction of blood transfusion by using SI may be used for the necessity of transfusion due to its high negative predictive value. The strength of our scoring system lies in the systematic evaluation of the necessity of transfusion according to the score. The ped-ABC score is composed of four points, whereas SI was composed of two choices: “yes” or “no.” It could be used not only for rule-out but also for rule-in. Moreover, our scoring system does not require different cut off points according to patient age. In addition, our scoring system is non-invasive and can be used quickly, whereas other studies require laboratory tests [26, 27]. Further studies are needed to assess our scoring system.

## **Ability, utility, and implementation of ped-ABC score**

The ped-ABC score may be better than the clinical gestalt [28]. Clinicians are sometimes forced to choose between delaying transfusion or risking transfusion-related complications. Indeed, the majority of pediatric arrivals with trauma do not initially show clear indications for transfusion [11]. Our scoring system enables clinicians to evaluate or discuss the need for transfusion by using common criteria. Based on our ped-ABC scores, blood transfusion might be reasonable for patients with a score of 3 or 4. However, it may be more controversial when a clinician examines patients with a score of 2, though some over-triage for transfusion might be tolerated from the clinical point of view, especially for children. Delaying transfusion until the worsening of vital signs or coagulopathy in the course of examination would be an alternative to administering transfusion. Ultimately, a final decision would be needed regarding transfusion. Although the scoring system may not have the ability to predict outcomes perfectly, it can still help clinicians to make a systematic evaluation through a simplified method.

## **Limitations**

This study has several limitations. First, approximately 30% of data of FAST scan were not conducted. These might have been the cases where a clinician considered FAST scan unnecessary because of mild state or because they shared a critical status. However, these patients did not need our scoring system to evaluate the requirement of blood transfusion. Second, a validation study is needed since this study was retrospective. Third, there might have been an indication bias of transfusion because we did not have the data of appropriateness of treatments. In 2002, a guideline for trauma care named Japan Advanced Trauma Evaluation and Care was introduced in Japan. It was created with reference to the Advanced trauma life support practice theory. In addition, all participating institutions were national-certified emergency centers. Therefore, we believe that most patients received appropriate treatments. Fourth, data about transfusion history is missing in the study; however, as this is a very small proportion (3.9%), we consider it to have little effect on our results. Fifth, the requirement for transfusion is not the same as the urgency or the appropriateness of transfusion. Further studies are warranted to evaluate whether the ped-ABC score could reduce the time to implement transfusion and improve patient outcomes. Sixth, we focused on simplicity when we developed a scoring system to predict the need for transfusion. Consequently, the scoring system's c-statistic may not be very high. However, we believe that our score is useful in that it makes fast and easy assessment possible at an early phase of trauma survey.

## Conclusions

We developed the ped-ABC score: the scoring system to predict requirement for transfusion with 24 hours for children with trauma using vital signs and FAST.

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## List Of Abbreviations

ABC Assessment of Blood Consumption

AIS Abbreviated Injury Scale

CI Confidence interval

ED Emergency department

FAST Focused assessment with sonography for trauma

GCS Glasgow Coma Scale

HR Heart rates

ISS Injury Severity Score

JTDB Japan Trauma Data Bank

SBP Systolic blood pressure

SI Shock index

Ped-ABC score The Assessment of Blood Consumption score for pediatrics

## **Declarations**

# **Ethical Approval and consent to participate**

We received the permission to use the data from the steering committee of the JTDB. The study protocol was reviewed and approved by the ethics committees of Juntendo University Hospital. The ethics committees waived the need to obtain informed consent from the study participants, given the retrospective and anonymized nature of this study in the routine care. All methods were carried out in accordance with the relevant guidelines and regulations.

### **Consent for publication**

Not applicable

### **Availability of data and materials**

The datasets analyzed during the current study is available with the corresponding author on reasonable request.

### **Competing interests**

All authors declare that they have no competing interests.

## **Funding**

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## **Author contributions**

AK conceived of and designed this study, interpreted the data, drafted the manuscript, and revised the manuscript for important intellectual content. TA contributed to the acquisition of data, conceived of and designed this study, interpreted the data, and revised the manuscript for important intellectual content. GD, MA, and DS contributed to interpreted the data, and revised the manuscript for important intellectual content. All of the authors contributed to the acquisition of data, reviewed, discussed, and approved the final manuscript.

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## References

1. Mokdad AH, Forouzanfar MH, Daoud F, Mokdad AA, El Bcheraoui C, Moradi Lakeh M, et al. Global burden of diseases, injuries, and risk factors for young people's health during 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013. *The Lancet*. 2016;387:2383–401.
2. Cunningham RM, Walton MA, Carter PM. The major causes of death in children and adolescents in the United States. *N Engl J Med*. 2018;379:2468–75.
3. Spady DW, Saunders DL, Schopflocher DP, Svenson LW. Patterns of injury in children: a population-based approach. *Pediatrics*. 2004;113:522–9.
4. Powell EK, Hinckley WR, Gottula A, Hart KW, Lindsell CJ, McMullan JT. Shorter times to packed red blood cell transfusion are associated with decreased risk of death in traumatically injured patients. *J Trauma Acute Care Surg*. 2016;81:458–62.
5. Strumwasser A, Speer AL, Inaba K, Branco BC, Upperman JS, Ford HR, et al. The impact of acute coagulopathy on mortality in pediatric trauma patients. *J Trauma Acute Care Surg*. 2016;81:312–8.
6. Avarello JT, Cantor RM. Pediatric major trauma: an approach to evaluation and management. *Emerg Med Clin North Am*. 2007;25:803–36.
7. Oakley FD, Woods M, Arnold S, Young PP. Transfusion reactions in pediatric compared with adult patients: a look at rate, reaction type, and associated products. *Transfusion*. 2015;55:563–70.
8. Yucel N, Lefering R, Maegele M, Vorweg M, Tjardes T, Ruchholtz S, et al. Trauma Associated Severe Hemorrhage (TASH)-Score: probability of mass transfusion as surrogate for life threatening hemorrhage after multiple trauma. *J Trauma*. 2006;60:1228–36. discussion 1236-7.
9. Nunez TC, Voskresensky IV, Dossett LA, Shinall R, Dutton WD, Cotton BA, et al. Early prediction of massive transfusion in trauma: simple as ABC (assessment of blood consumption)? *J Trauma*. 2009;66:346–52.
10. Ott R, Kramer R, Martus P, Bussenius-Kammerer M, Carbon R, Rupprecht H. Prognostic value of trauma scores in pediatric patients with multiple injuries. *J Trauma*. 2000;49:729–36.
11. Kamyszek RW, Leraas HJ, Reed C, Ray CM, Nag UP, Poisson JL, et al. Massive transfusion in the pediatric population: A systematic review and summary of best-evidence practice strategies. *J Trauma Acute Care Surg*. 2019;86:744–54.
12. Japan Trauma Care and Research. Japan Trauma Data Bank Report Japan Trauma Data Bank Report 2018 (2013–2017). Available at: <https://www.jtcr-jatec.org/traumabank/dataroom/data/JTDB2018e.pdf>. Accessed November 4, 2019. Published December 17, 2018.

13. Gonzalez KW, Desai AA, Dalton BG, Juang D. Hemorrhagic Shock. *J Pediatr Intensive Care*. 2015;4:4–9.
14. Ko A, Harada MY, Murry JS, Nuno M, Barmparas G, Ma AA, et al. Heart rate in pediatric trauma: rethink your strategy. *J Surg Res*. 2016;201:334–9.
15. de Caen AR, Berg MD, Chameides L, Gooden CK, Hickey RW, Scott HF, et al. Part 12: Pediatric Advanced Life Support: 2015 American Heart Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation*. 2015;132:526-42.
16. Subcommittee A, American College of Surgeons' Committee on T, International Awg. Advanced trauma life support (ATLS(R)): the ninth edition. *J Trauma Acute Care Surg*. 2013;74:1363–6.
17. Kanda Y. Investigation of the freely available easy-to-use software 'EZR' for medical statistics. *Bone Marrow Transplant*. 2013;48:452–8.
18. Beskind DL, Keim SM, Spaite DW, Garrison HG, Lerner EB, Howse D, et al. Risk adjustment measures and outcome measures for prehospital trauma research: recommendations from the emergency medical services outcomes project (EMSOP). *Acad Emerg Med*. 2011;18:988–1000.
19. Hannan EL, Farrell LS, Meaker PS, Cooper A. Predicting inpatient mortality for pediatric trauma patients with blunt injuries: a better alternative. *J Pediatr Surg*. 2000;35:155–9.
20. Yousefzadeh-Chabok S, Kazemnejad-Leili E, Kouchakinejad-Eramsadati L, Hosseinpour M, Ranjbar F, Malekpouri R, et al. Comparing Pediatric Trauma, Glasgow Coma Scale and Injury Severity scores for mortality prediction in traumatic children. *Ulus Travma Acil Cerrahi Derg*. 2016;22:328–32.
21. Riera A, Hayward H, Silva CT, Chen L: Reevaluation of FAST sensitivity in pediatric blunt abdominal trauma patients: Should we redefine the qualitative threshold for significant hemoperitoneum? *Pediatric Emergency Care* 2019.
22. Kessler DO. Abdominal Ultrasound for Pediatric Blunt Trauma: FAST Is Not Always Better. *JAMA*. 2017;317:2283–5.
23. Bruijns SR, Guly HR, Bouamra O, Lecky F, Lee WA. The value of traditional vital signs, shock index, and age-based markers in predicting trauma mortality. *J Trauma Acute Care Surg*. 2013;74:1432–7.
24. Nordin A, Coleman A, Shi J, Wheeler K, Xiang H, Acker S, et al. Validation of the age-adjusted shock index using pediatric trauma quality improvement program data. *J Pediatr Surg*. 2017;53:130–5.
25. Strutt J, Flood A, Kharbanda AB. Shock index as a predictor of morbidity and mortality in pediatric trauma patients. *Pediatr Emerg Care*. 2019;35:132–7.
26. Golden J, Dossa A, Goodhue CJ, Upperman JS, Gayer CP. Admission hematocrit predicts the need for transfusion secondary to hemorrhage in pediatric blunt trauma patients. *J Trauma Acute Care Surg*. 2015;79:555–62.
27. Smith SA, Livingston MH, Merritt NH. Early coagulopathy and metabolic acidosis predict transfusion of packed red blood cells in pediatric trauma patients. *J Pediatr Surg*. 2016;51:848–52.
28. Pommerening MJ, Goodman MD, Holcomb JB, Wade CE, Fox EE, Del Junco DJ, et al. Clinical gestalt and the prediction of massive transfusion after trauma. *Injury*. 2015;46:807–13.

# Figures

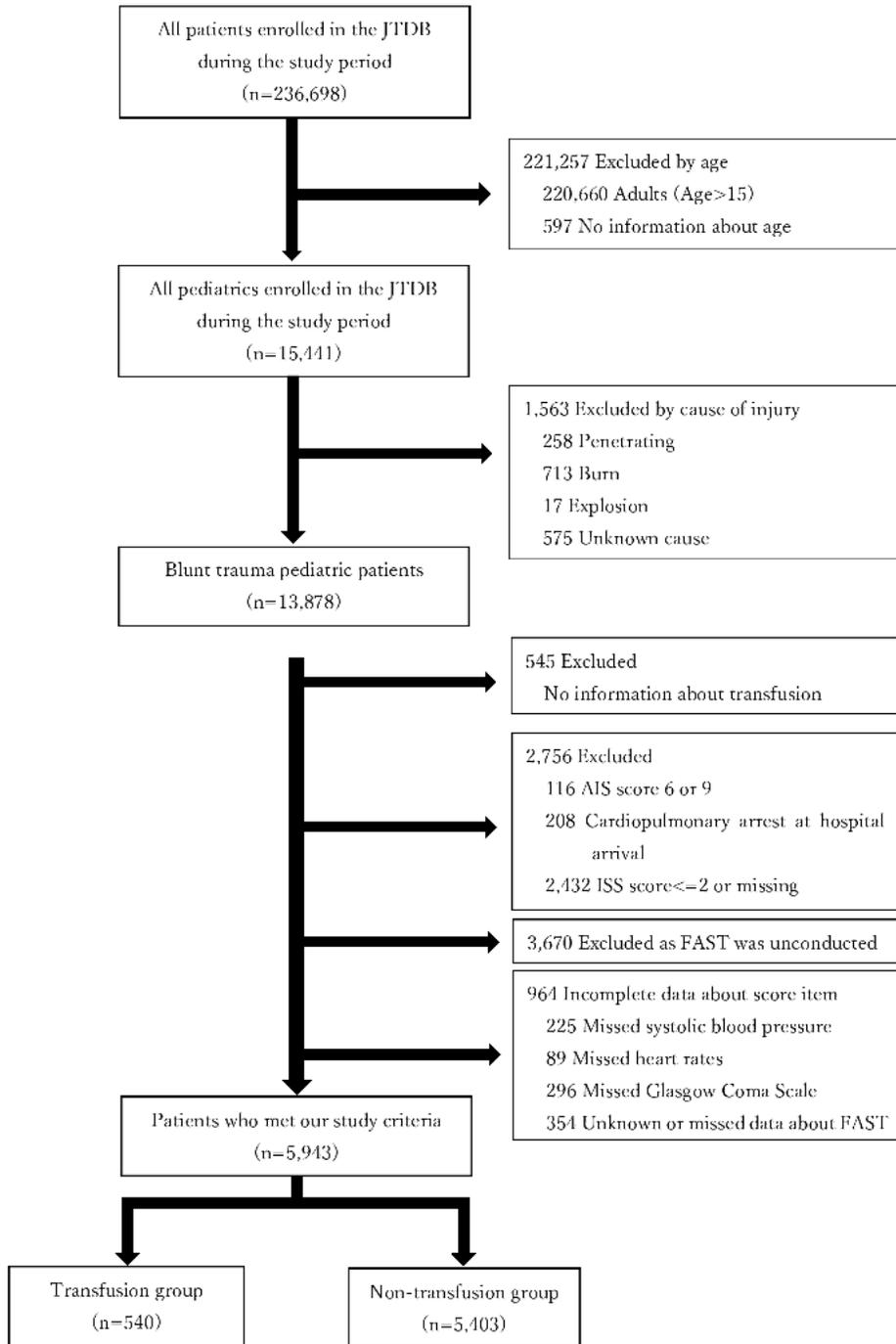


Figure 1

Flow of study participants

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