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The ABC-D score improves the sensitivity in predicting need for massive transfusion in pediatric trauma patients

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ABSTRACT

Purpose: Early and accurate identification of pediatric trauma patients who will require massive transfusion (MT) remains difficult, and MT activation criteria are not well established. In children, the addition of shock index-pediatric age-adjusted (SIPA) to the ABC score (ABC-S) only modestly improves the sensitivity of the ABC score. We hypothesized that the discriminate ability of the ABC-S score would improve with the addition of elevated serum lactate and base deficit (ABCD score).
Methods: We identified children between 1 and 18 years old who received a pRBC transfusion between 2008 and 2018 from our trauma registry. We calculated sensitivity, specificity, and accuracy of the ABC, ABC-S, and ABCD scores to determine the need for MT.
Results: We included 211 children, of which 66 required MT. The best predictor of MT was achieved by adding BD and lactate to the ABC-S score, with an AUC of 0.805. An ABCD score of 3 or greater was 77.4% sensitive and 78.8% specific at predicting the need for MT. Pediatric trauma patients that required MT had higher injury severity score ($p = 0.005$), lactate ($p = 0.002$), base deficit ($p = <0.0001$). Mortality was higher in the MT group (45.5% vs 15.3%, $p = 0.0004$).
Conclusions: The ABCD score improves the sensitivity of activating MT in pediatric trauma patients.
Study Type: Treatment Study.
Level of Evidence: Level III.

Every year over 10,000 US children and adolescent patients die from traumatic injuries, making trauma the principal cause of death in this population [1–3]. Uncontrolled hemorrhage leading to cardiovascular collapse remains one of the most common causes of preventable death [4]. Children have an increased physiologic reserve when compared to adults, and many can remain normotensive despite up to 45% blood loss, making predictors of decompensation and the need for resuscitation difficult [5]. Ongoing hemorrhage leads to the "lethal triad" of hypothermia, acidosis, and coagulopathy with the treatment pendulum shifting to early hemorrhage control and damage control resuscitation (DCR) [6,7].

It is well established that these early interventions aimed at correcting coagulopathies in trauma are associated with improved survival [8,9]. DCR involves the resuscitation of a bleeding patient with a defined ratio of component therapy, including equal parts of packed red blood cells (PRBC), fresh frozen plasma (FFP), and platelets (PLT). Recently, the ATOMAC group has shown that a 1:1 pRBC to FFP ratio in pediatric massive transfusion (MT) has a survival advantage compared to transfusions with higher ratios of pRBC [10].

The understanding that earlier initiation of a large volume of balanced blood component transfusion is associated with improved survival has led to the development of massive transfusion protocols (MTP); however, MTPs lack a consensus definition in children, as well as consensus on specific triggers to activate MTPs. The decision to activate an MTP is often at the discretion of the physician [11]. In adults, the development of the assessment of blood consumption (ABC) score gives one point for each of the following: penetrating mechanism, positive focused abdominal sonography for trauma (FAST), systolic blood pressure (SBP) <90, and heart rate (HR) >120 [12]. A score of 2 or higher has been used as a trigger to activate MTP. Previous work has shown that the adult-based activation criteria, namely the ABC score, performs poorly in children with a much lower sensitivity for MTP activation.

Additionally, the replacement of HR and BP cutoffs in the ABC score with the age-adjusted shock index (SIPA) (the ABC-S score) only

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slightly improved the accuracy of ABC-S as a triage tool [13]. It is important to remember that in pediatric patients, vital signs vary by age, and SIPA better identifies severely injured children [14,15] In addition to age-adjustment of vital signs, the ABC score does not take into account the physiologic derangements of the lethal triad that are associated with worse outcomes, which limit its ability to accurately predict MTP in pediatric patients. Finally, early initiation of a MTP allows a blood bank to prepare adequate volumes of component therapy to ensure a balanced resuscitation, while also limiting wastage of blood products and resources. A recent systematic review highlighted the need for further research into the initial triggers of MTP in children [16].

This led us to hypothesize that the discriminate ability of the ABC-S score would improve with the addition of elevated serum lactate and base deficit (ABCD) score. We aimed to determine if modifications to the adult-based ABC score with the inclusion of base deficit and lactate (ABCD) and age-adjustments for vital signs (ABC-S) would improve the discriminate ability to predict massive transfusion requirements in pediatric trauma.

1. Material and methods

1.1. Study design

We retrospectively examined all highest-level pediatric trauma activations admitted between January 2008 to December 2018 in our prospectively collected trauma registry at Children's Hospital Colorado (CHCO), which serves as the state's only American College of Surgeons level I pediatric trauma center. We included pediatric patients (≤18 years old) who received at least one blood product transfusion within the first 24 hours after their injury. We excluded children who died in the emergency department and children <1-year-old because SIPA scores have not been validated in this age group. The Colorado Multi-Institutional Review Board at the University of Colorado approved this study.

1.2. Data collection

We collected study data on demographic characteristics, mechanism of injury, injury severity score (ISS), and Glasgow Coma Score (GCS). We collected all first available laboratory values on admission to our emergency department, except for those patients who received blood products at an outside facility, in which case the laboratory values before transfusion if available were used. We recorded total milliliters (ml) of all blood products transfused (packed red blood cells (pRBC), fresh frozen plasma (FFP), and platelets) at the first four, six, and twenty-four hours following injury. Using receiver operator curve (ROC) analysis an optimal definition of MT was determined to be ≥40 cc/kg of total blood product within the first 6 hours following their injury. At CHCO, the decision to activate MT is at the trauma surgeon's discretion. In general, however, an MTP is activated when the trauma surgeon believes the patient will have "a predicted blood loss of 50% of blood volume in three hours or less and/or there is active bleeding and the patient has already received ≥40 mL/kg crystalloid and ≥20 mL/kg blood".

1.3. Statistical analysis

Demographic data were compared using chi-squared or Fischer's exact and t-tests for categorical and continuous data, respectively. ABC scores were calculated based on: penetrating mechanism, positive FAST, systolic blood pressure (SBP) <90, and heart rate (HR) >120. Age-adjusted ABC scores (ABC-S) were calculated by substituting SIPA for HR and SBP. Using a ROC, we simultaneously maximized sensitivity and specificity and defined optimal cutoffs for lactate at >3.5 and base deficit (BD) >−8.8. ABCD scores were calculated by combining penetrating mechanism, positive FAST, SIPA, lactate, and BD. The sensitivity, specificity, and accuracy of each score were calculated based on the need for MT. Significance was set at $p < 0.05$. R version 3.4.1 software (R Foundation for Statistical Computing, Vienna, Austria, http://www.R-project.org/) was utilized.

Table 1
Demographic and injury pattern characteristics divided into non-MT and MT.

	No MT (n = 144)	MT (n = 66)	p-Value[a]
Age, mean (SD)	9.1 (± 5.0)	8.0 (± 5.1)	0.18
Male, n (%)	96 (67%)	45 (68%)	0.95
Mortality, n (%)	22 (15%)	30 (45%)	<0.0001
ISS, mean (SD)	28 (± 13)	34 (± 15)	0.005
Temperature, mean (SD)	36 (± 1.3)	36 (± 2.5)	0.08
SIPA, mean (SD)	1.2 (± 0.40)	1.6 (± 0.69)	<0.0001
GCS, mean (SD)	7.6 (± 5.2)	5.8 (± 4.7)	0.018
Penetrating mechanism, n (%)	13 (9%)	8 (12%)	0.66
Positive FAST, n (%)	13 (9%)	12 (18%)	0.09
Lactate, mean (SD)	3.2 (± 2.6)	5.6 (± 4.0)	0.002
BD, mean (SD)	-6.4 (± 4.1)	-13 (± 5.4)	<0.0001

Abbreviations: MT, massive transfusion; SD, Standard deviation; ISS, injury severity score; SIPA, age-adjusted shock index; GCS, Glasgow Coma Score; FAST, focused assessment with sonography for trauma; BD, base deficit.

[a] Comparisons were made between no massive transfusion and massive transfusion, using chi-squared or Fischer's exact and t-tests for categorical and continuous data, respectively.

2. Results

2.1. Cohort description

During the study period, 211 children received a blood transfusion within the first 24 hours of injury; 66 required MT. Interestingly, none of the patients in the non-MT group received enough additional blood products between hours six and 24 after their injury to push them over ≥40 cc/kg of total blood products that is traditionally used to define MT in pediatric trauma. Additionally, 31% (44/144) of the non-MT group did not receive their first blood product until 6 hours after injury. Demographic and injury parameter data are presented in Table 1.

We found no significant difference in age (8.0 ± 5.1 vs. 9.1 ± 5.0), male gender (68% vs. 67%), or temperature (36 ± 2.5 vs. 36 ± 1.3) between those who received MT compared to those who did not. Not surprisingly, mortality was higher in those that received MT (45.5% vs. 15.3%, p = <0.0001). Pediatric trauma patients that required MT had higher injury severity scores (34 ± 15 vs. 28 ± 13, p = 0.005), lactates (5.6 ± 4.0 vs. 3.2 ± 2.6, p = 0.002), and base deficits (−13 ± 5.4 vs. −6.4 ± 4.1, p = <0.0001). Overall, we found no significant differences between the groups, which had low combined rates of penetrating mechanism (10%) and a positive FAST exam (12%).

Table 2 demonstrates the sensitivity, specificity, and accuracy of the ABC, ABC-S, and ABCD at predicting the need for MT. We calculated sensitivity, specificity, and accuracy of ABC, ABC-S, and ABCD at values of 1, 2, and 3 to predict the need for MT. When developing the ABCD score, we found that adding lactate alone to the ABC-S score produced the lowest AUC of 0.684 (95% CI: 0.614, 0.755). Adding base deficit alone to the ABC-S score improved the AUC to 0.785 (95% CI: 0.725, 0.845). The best predictor of MT was found by adding both base deficit and lactate to the ABC-S score, to yield the ABCD score with an AUC of 0.805 (95% CI: 0.748, 0.863) (See Fig.1). The highest sensitivity for predicting MT was 97.9% for an ABCD score of 1 or higher, with a specificity of 40.4%. An ABCD score of 2 or higher was 87.4% sensitive and 52.5% specific at predicting the need for MT, while an ABCD score of 3 or higher was 77.4% sensitive and 78.8% specific.

3. Discussion

Early and accurate identification of pediatric trauma patients who will require MT remains challenging. Our study provides evidence that the novel ABCD score ≥1 is 97.9% sensitive at predicting the need for

Table 2
Ability of ABC, ABC-S, ABCD scores to predict the need for massive transfusion in pediatric trauma patients.

	Sensitivity	Specificity	Accuracy
ABCD (+ Base Deficit)			
≥1	96.4%	41.3%	55.7%
≥2	83.9%	56.9%	73.8%
≥3	73.2%	75.0%	73.3%
ABCD (+ Lactate)			
≥1	87.7%	38.6%	51.9%
≥2	76.5%	52.6%	70.0%
≥3	69.5%	50.0%	68.6%
ABCD (+ Base Deficit & Lactate)			
≥1	**97.9%**	40.4%	53.8%
≥2	87.4%	52.5%	70.9%
≥3	77.4%	**78.8%**	**77.6%**
ABC			
≥1	85.2%	37.2%	49.5%
≥2	78.0%	55.0%	71.4%
≥3	69.0%	54.5%	69.1%
ABC-S			
≥1	84.5%	39.6%	54.7%
≥2	71.6%	47.1%	67.6%
≥3	68.3%	0.0%	67.6%

Note: Boldfaced values indicate the cutoff criteria with the highest sensitivity, specificity, and overall accuracy, respectively.

MT in pediatric trauma patients. The ABCD score uses SIPA instead of adult based cutoffs for BP and HR, and includes two indicators of systemic acidosis (base deficit and lactate) to yield a sensitive and specific score for activating pediatric MT. One significant advantage of the ABCD score is that it is a simple, unweighted score that can be calculated at the bedside. While the ABCD score had the best ability to predict the need for MT, the ABC score and ABC-S scores ≥1 both had sensitivity >80% at predicting MT. While the ABCD score does have excellent sensitivity, it is less specific for MT activation, which has the potential for over activation of MT with increased cost and wastage of the blood products and resources.

Base deficit (BD) and lactate have been used as biochemical markers of shock and mortality since the 1960s [17,18]. BD and lactate have been shown to be significantly associated with the need for blood transfusion, adequacy of resuscitation, and mortality in trauma patients [19]. In pediatric trauma patients, there is no standard cutoff for base deficit or lactate when trying to identify those patients who need massive transfusion. One study found that only 7% of pediatric trauma centers reported using labs as a trigger for MT [11]. We found cutoffs of >3.5 for lactate and a base deficit (BD) of > − 8.8 to be the optimal points

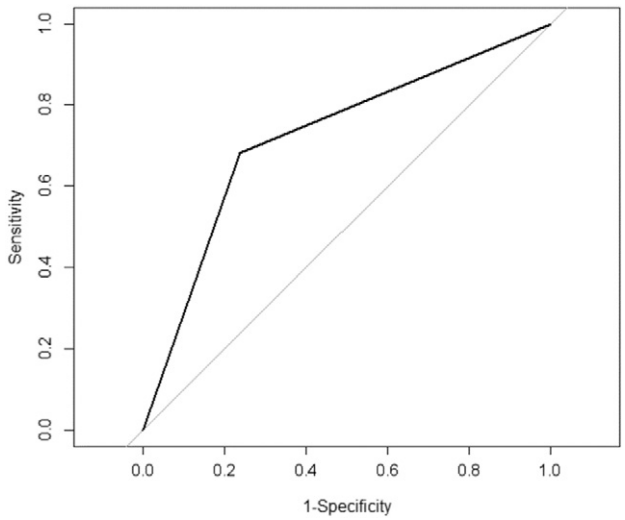

Fig. 1. Receiver operator curve dichotomized for an ABCD score ≥2 for predicting need for massive transfusion.

to consider activation of MTP. Further work needs to be done to validate and incorporate lab abnormalities into activation criteria for MTP.

Nunez et al. found the ABC score to be 75% sensitive and 86% specific in predicting massive transfusion in adult patients [12]. Early activation of massive transfusion protocols and damage control resuscitation has resulted in a significant decrease in mortality in adult trauma patients, but remains undefined in pediatric patients. The ABC score, which is used in adult MTP activations, is limited in pediatric trauma patients due to low rates of penetrating injuries (10% in our cohort) and positive FAST exams (12% in our cohort). While the FAST exam has high sensitivity and specificity in the adult trauma population, FAST lacks sensitivity in the pediatric trauma population, due to wide variability in user experience and expertise [20].

To date, there remains a paucity of literature on the appropriate triggers of MT in pediatric patients and protocols vary by the institution [16]. Controversy remains regarding what defines massive transfusion in pediatric trauma [10,16]. Massive transfusion is most often defined in pediatric patients as transfusion volumes of ≥40 cc/kg of total blood products over the first 24 h after injury, which was found to be the cutoff associated with worse outcomes [21]. There is a critical need for more research in pediatric massive transfusion. We activate MTP at our center based on the discretion of the physician who "predicts blood loss of 50% of blood volume in three hours or less" and active bleeding in which the patient has already received ≥40 mL/kg crystalloid and ≥20 mL/kg blood. We are now working to incorporate SIPA, base deficit, and lactate into our activation criteria.

3.1. Limitations

There are several limitations to our study, given its retrospective nature with a small sample size of patients. Pediatric trauma patients have low rates of penetrating trauma and positive FAST exams. In our cohort, 48% overall, and 59% of those who received MT did not undergo a FAST exam. The FAST exam is operator dependent and less accurate in smaller children. Another limitation of this study includes selection bias as we are evaluating these scores in a high-risk patient population, which includes the highest level pediatric trauma activations who receive at least one unit of blood products. For this reason, the results may not be applicable to a more general population of pediatric trauma patients. Larger-scale prospective studies are required to develop predictive models that will improve early identification of pediatric patients who will require MT.

4. Conclusions

In conclusion, the ABCD score, which substitutes adult vital signs with SIPA and adds base deficit and lactate to the ABC-score, improves the sensitivity at predicting which pediatric trauma patients will require MT. For each point increase in the ABCD score, the accuracy and balance between sensitivity and specificity improves, suggesting it may be a useful tool to expedite the delivery of blood products during a trauma resuscitation.

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