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Pediatric Specific Assessment Modalities in Pediatric Blunt Trauma Cases: A Literature Review

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Abstract

With unintentional injury being the number one cause of death of children in the United States, it warrants the need for successful, cost effective ways to improve identification of severe injury and prevent mortality in children. The purpose of this review is to compile literature related to pediatric specific trauma assessments in the instance of blunt trauma. Twenty peer-reviewed articles that were published in notable journals were analyzed to include in this review. There are several assessments that are being utilized in pre-hospital and hospital emergency settings today, such as the Shock Index (Pediatric Age Adjusted), Pediatric BIG Score, and variations of the Injury Severity Score. Other variables analyzed that have an impact on patient outcomes include socioeconomic status, trauma center type, and availability of resources. While research comparing the successes and shortcomings of these assessments are limited, it is crucial for healthcare professionals to understand the components of each of these assessments so that they may decide which one to implement considering the resources available.

Introduction

Accidental injury is the number one leading cause of death in children ages 1-19, representing 35% of all deaths in this age category in 2016 (Centers for Disease Control, 2018). Of these, 3,461 deaths were the result of a traumatic mechanism of injury, with 1,956 deaths caused by a potential source of blunt trauma, shown in Table 1 (American College of Surgeons, 2016). These statistics not only reveal that blunt trauma greatly affects the pediatric population, but also suggests that current assessment methods might be insufficient in predicting injury severity, leading to higher mortality rates.

Traditionally, pediatric patients presenting with blunt trauma injuries might be assessed the same way as adult patients with the same mechanism of injury. However, significant anatomical, physiological, and psychosocial differences between adults and children necessitate the use of assessments that are catered exclusively to the pediatric population in the instance of blunt trauma cases to better predict severe injury (McFadyen et al., 2012). These differences have major implications in the primary survey and identification of life-threatening injuries in children. Early recognition and treatment of airway obstruction, inadequate ventilation, oxygenation, and impaired circulatory function improves patient outcomes; but health care providers must be aware that children are not simply "small adults". Presenting signs and symptoms that indicate severe injury differ from the adult population. For example, children have the ability to maintain blood pressure and heart rate despite significant acute blood losses (25%-30%), demonstrating that subtle changes in blood pressure, heart rate, or extremity perfusion could indicate impending cardiorespiratory failure (Avarello & Cantor, 2007). Additionally, proportionately large body surface area relative to body weight predisposes the pediatric patient to insensible heat and water loss, as well as a greater distribution of force during

a traumatic injury, leading to multiple organ damage and higher degree of injury (Avarello &

Cantor, 2007).

While several pediatric specific assessment modalities have been put into practice within

pre-hospital and hospital emergency settings, there is a clear gap in the literature regarding which

method is most effective in predicting severity of injury as well as mortality. This literature

review provides an in depth look into the effectiveness and limitations of three different

assessment modalities: Pediatric BIG Score, SIPA, and wISS, as well as information about

current models that could be modified to better suit the pediatric population. Additionally, it

provides insight into how pediatric specific trauma assessments can help health care facilities

utilize and allocate their resources more effectively.

Table 1

Table 1
Leading causes of traumatic deaths in ages 1-19 in the US – 2016
National Trauma Data Bank Pediatric Annual Report 2016

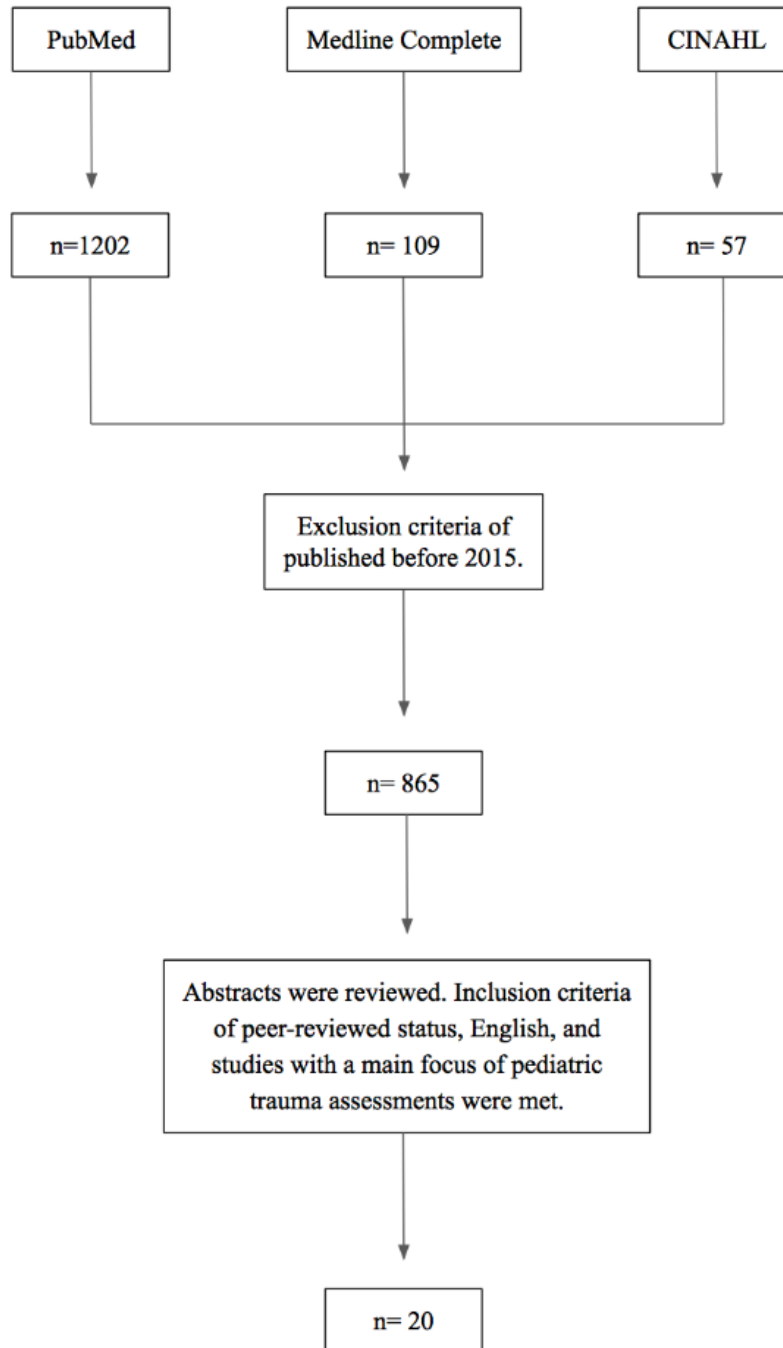| Etiology	No.	%
Motor Vehicle Accident*	1065	30.8%
Fall*	704	20.3%
Firearm	695	20.1%
Suffocation	61	1.8%
Drowning	36	1%
Fire/burn	43	1.2%
Struck by, against*	187	5.4%
Other	670	19.4%

* Potential source of blunt trauma

Methods

A systematic review of literature was conducted using MEDLINE Complete, PubMed, and CINAHL. One primary investigator, myself, searched each database using the subject headings *pediatric, blunt trauma* and *assessment*. The search limiters placed on each database search included key words, English language, and peer-reviewed status. Excluded from the review were articles published prior to the year 2015 and whose main topic was not relevant to pediatric trauma assessment.

My initial search in PubMed yielded 1202 results, but exclusion criteria eliminated 433 articles, leaving 796 articles that were published after 2015. These were reviewed to ensure inclusion criteria were met. Of these articles, 15 were found to be relevant to this research that discussed shock index, benchmarking tools for low-resource settings, weighted injury severity score, and patient outcomes within pediatric facilities. The search performed in CINAHL resulted in 57 articles, with 17 of those being eliminated due to exclusion criteria. Three articles reviewed a novel trauma composite score and pediatric BIG score and were found as relevant to be utilized in this review. MEDLINE Complete produced 109 articles, after reviewing exclusion criteria, 56 results remained. After analyzing the remaining results, two articles were ultimately chosen to include, discussing shock index and BIG score. Once all of the literature was carefully examined, a total of 20 articles were found to be relevant and are the focus of this review.

Figure 1

Selection of retrieved articles

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   ┌──────────┐      ┌──────────────────┐      ┌──────────┐
   │ PubMed   │      │ Medline Complete │      │ CINAHL   │
   └────┬─────┘      └────────┬─────────┘      └────┬─────┘
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   ┌──────────┐      ┌──────────────────┐      ┌──────────┐
   │ n=1202   │      │ n= 109           │      │ n= 57    │
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                 │ Exclusion criteria of    │
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                        │ n= 865   │
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        ┌────────────────────────────────────────┐
        │ Abstracts were reviewed. Inclusion      │
        │ criteria of peer-reviewed status,       │
        │ English, and studies with a main focus  │
        │ of pediatric trauma assessments were    │
        │ met.                                    │
        └────────────────────┬───────────────────┘
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                        │ n= 20    │
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Results

Shock Index, Pediatric Age-Adjusted

Shock index (SI) is a routinely performed bedside assessment on patients who are at risk of or are experiencing trauma, hemorrhage, myocardial infarction, pulmonary embolism, or sepsis (Koch et al., 2019). This metric is defined as heart rate (HR) divided by systolic blood pressure (SBP). In healthy patients, this ratio is expected to be 0.5-0.7, while in injured patients, a SI > 0.9 recognizes increased risk of mortality, activation of mass transfusion protocol, and ICU admission (Koch et al., 2019). Another triage tool uniformly used across trauma centers is the revised trauma score (RTS). The RTS consists of respiratory rate (RR), SBP, and Glascow Coma Scale (GCS) (Acker et al., 2015). While both of these assessments have shown to be an effective measure of injury severity in adults, the same can't be said when being utilized in the pediatric patient population. In children, these factors are hard to measure accurately due to the fact that normal vital signs vary greatly with patient age. However, several studies have been conducted to evaluate which factors most accurately predict injury severity and outcomes in pediatric patients.

Data suggests that mechanism of injury is a poor predictor of injury severity when used independently, and that physiologic parameters are better suited in determining major trauma (Acker et al., 2015). Acker et al. (2015) predicted that modifying the traditional SI scoring system to allow for age-adjusted values could be a more reliable way to predict outcomes among children with blunt trauma injuries. The shock index, pediatric adjusted (SIPA) scoring system would instead use cut off values that are unique to patient age, as opposed to the adult derived value that was previously discussed. When SIPA was compared to SI, it was shown that both

methods were able to accurately predict severe injury. However, SIPA better differentiates the most severely injured children from those with mild injury, more accurately predicting patients who required blood transfusion within 24 hours, longer intensive care unit (ICU) length of stay, and higher number of days on the ventilator (Acker et al., 2015).

Strutt et al. (2019) agrees that when compared with unadjusted SI, SIPA improves identification of negative outcomes after blunt trauma, suggesting that SI is "a more sensitive marker of hemodynamic instability compared with traditional vital signs" (Strutt et al., 2019, p. 133). This study also noted that the addition of delayed capillary refill to SBP measurements can further indicate early acute hypovolemia. Due to unique compensatory mechanisms that children have to maintain blood pressure, peripheral tissues often vasoconstrict, thus causing delayed capillary refill. In addition, SIPA has been shown to accurately predict the need for blood transfusion. Research conducted by Phillips et al. (2020) stated that measuring serial SIPA scores from the pre-hospital to hospital setting can assist in identifying children who require blood transfusion due to blunt trauma sustained to a solid organ. Ninety percent of the patients requiring blood transfusion had at least one elevated SIPA score in either setting (pre-hospital or emergency room [ER]). The authors concluded that an elevated SIPA score was significantly associated with blood transfusion. (Phillips et al., 2020). SIPA is not only useful on arrival to the ER and during the primary survey, but also after admission to the PICU. Huang et al. (2021) hypothesized that an increase in SIPA score during the first 24 hours of admission to the PICU would correlate to adverse outcomes. In the study, SIPA values were collected upon admission to the ER, and again after 24 hours spent in the ICU. Of the 1,732 patients included, results demonstrated that an elevated SIPA did in fact predict higher rates of mortality and adverse

outcomes such as a need for ventilatory and inotropic support, as well as a longer hospital length of stay (Huang et al., 2021).

Conversely, Lammers et al. (2020) stated that the addition of neurological status to SIPA would provide superior prognostic capabilities than SIPA alone. Instead of dividing HR by SBP to obtain a standard SIPA score, it was calculated inversely (SBP/HR) to obtain reverse shock index (rSIG). To finalize the score, rSIG was then multiplied by GCS. Like SIPA, values for each age cohort were assigned to address the discrepancies in normal ranges in pediatric vital signs. It was found that rSIG multiplied by GCS did predict hospital mortality more readily than SIPA (Lammers et al., 2020). This demonstrated that neurological status should be an important factor in the initial primary survey. However, further assessment of the utility and applicability of this metric is necessary.

Another factor to include when considering major trauma patient outcomes is the type of trauma center. Pediatric trauma patients are treated at adult trauma centers (ATCs), mixed pediatric and adult trauma centers (MTCs), and pediatric trauma centers (PTCs) (Austin et al., 2021). Knowing that SIPA is an effective tool that has been validated to identify severely injured children and their outcomes, it can also be used to determine the most ideal trauma center type for this patient population. PTCs possess the ability to provide specialized care to children and are equipped with pediatric specialists and resuscitation equipment. However, PTCs are limited in their geographic availability, and the majority of pediatric trauma patients in the United States are treated at either ATCs or MTCs (Austin et al., 2021). Previous studies suggest that pediatric patients have a lower mortality rate at PTCs when compared to ATCs or MTCs, however, there seems to be conflicting evidence. Austin et al., (2021) states that among pediatric trauma patients with an elevated SIPA, there was no difference in mortality between trauma center types (Austin

et al., 2021). Specialty care at PTCs optimizes the care of pediatric trauma patients due to a number of factors.

Pediatric BIG Score

Much like the SIPA scoring system, the pediatric BIG score is used to stratify severity of injury and predict mortality; however, it is much newer. The BIG score is utilized because of its simplicity and easily accessible assessment data. Due to the fact that vital signs don't contribute to the BIG score, it could be more reliable than SIPA because normal vital signs greatly differ with age. What makes the BIG score unique is that it is composed of three physiological measurements that play a critical role in children's survival: base deficit (BD), international normalized ratio (INR) and GCS (Grandjean-Blanchet et al., 2018). Base deficit reflects shock status, INR can indicate early trauma related coagulopathy, and GCS assesses level of consciousness, reflecting the degree of brain injury or hypoperfusion. Together, these values provide a quick view of two of the most common causes of mortality in pediatric blunt trauma: brain injury and hemorrhagic shock (Davis et al., 2015). Grandjean-Blanchet et al. (2018) states that the BIG score outperformed the injury severity score (ISS), as well as predicted mortality significantly better than INR and BD alone. The BIG score is calculated as follows: (BD) + (2.5 × INR) + (15-GCS). A score <16 accurately identifies children with a high probability of survival (Grandjean-Blanchet et al., 2018). Davis et al., (2015) agrees that the BIG score demonstrated an accurate prediction of mortality in pediatric patients with blunt trauma, however, adds that results can be erroneous after the administration of medications and fluids. Similarly, Yoon et al. (2021) found that the BIG score is an excellent predictor of mortality in normotensive pediatric trauma patients. This study examined 1046 patients under the age of 18 in South Korea and excluded those with age-adjusted hypotension. The aim of this study was to

validate the performance of the BIG score. It concluded that mortality was associated with a score >16, and found that the BIG score is much more accurate in predicting in-hospital mortality than the RTS (Yoon et al., 2021). Another study conducted by Bolstridge et al. (2021) shows that the BIG score is just as good, or better, than other commonly utilized assessment tools such as the Pediatric Risk of Mortality III (PRISM III) score, Pediatric Index of Mortality 2 (PIM2) score and Pediatric Logistic Organ Dysfunction (PELOD) score. Between the years of 2004-2015, 45,377 pediatric trauma patients from 149 PICUs were studied. After a logistic regression model was completed, the "Area under the Curve (AUC) of the BIG score was 0.94 compared to 0.96, 0.97 and 0.93 for the PRISM III, PIM2, and PELOD respectively" (Muisyo et al., 2019, p.1613).

Injury Severity Score

The Injury Severity Score (ISS) was established in 1974 as a universal injury severity metric, yet, does not take into account the physiologic differences in children, nor does it consider the differential risks of the Abbreviated Injury Scale (AIS), which classifies injury by six different body regions. ISS fails to represent patients who receive multiple injuries to the same body system (Keskey et al., 2021), and the mathematical formula used to calculate ISS often results in discrepancies (Shi et al., 2019). Additionally, children have lower mortality than do adults with the same ISS, thus, the accepted definition of severe injury is not equivalent (Hatchimonji et al., 2022; Brown et al., 2017).

Using retrospective analysis, Shi et al., (2018) collected data on previous pediatric blunt trauma patients with the objective of creating a weighted injury severity scoring (wISS) system that would outperform the traditional ISS. To do this, the association between mortality and AIS from each of the six ISS body regions was used to generate a scoring system that assigned

different weights for the various components of AIS. Results revealed that wISS showed "higher specificity, positive predictive value, negative predictive value, and better calibration" than ISS alone (Shi et al., 2018, p. 2). This data suggests that wISS is superior to ISS and has better predictive power for mortality.

See Table 2 for an outline of literature that was reviewed. Almost every study included utilized a retrospective cohort study design. While retrospective studies are an important tool to analyze outcomes of interventions, they have their limitations. While data is reliable, it should be noted that biases are often formed on the basis of the study findings, and can also include selection bias.

Table 2

Outline of reviewed literature

Davis, A. L., Malik, T., Razik, F., Schuh, S., Stephens, D., Wales, P. W.	2015	Canada	Retrospective cohort study	BIG score accurately predicted mortality in pediatric patients with blunt trauma, with a high possibility of survival (BIG <16).	Level IV evidence
Beaudin, M., Emeriaud, B., Grandjean-Blanchet, C., Gravel, J.	2017	Canada	Retrospective cohort study	BIG score was highly sensitive in predicting mortality in children (BIG $\geq$ 16).	Level IV evidence
Kharbanda, A. B., Flood, A., Strutt, J.	2019	United States	Retrospective cohort study	An elevated pediatric adjusted shock index (SIPA) was the strongest predictor for mortality in pediatric patients when compared shock index (hypotension and tachycardia).	Level IV evidence
Barlow, M., Bingham, J. R., Connor, J. R., Eckert, M. J., Escobar, M. A., Horton, J. D., Lammers, D. T., Marenco, C. W., Martin, M. J., Morte, K. R.	2021	United States	Prognostic study	Neurological status is an important factor as part of the initial patient assessment, as reverse shock index (rSIG) multiplied by GCS more accurately predicted mortality in pediatric patients when compared to SIPA.	Level IV evidence
Austin, J. R., Chao, S. D., Lee, M. O., Ye, C.	2021	United States	Retrospective cohort study	Among pediatric patients with an elevated SIPA score, there was no significant difference in mortality between those treated at a pediatric	Level IV evidence

				trauma center rather than at an adult trauma center.	
Acker, S. N., Bensard, D. D., Partrick, D. A., Ross, J. T., Tong, S.	2015	United States	Retrospective cohort study	SIPA more accurately identified pediatric patients with severe injury requiring blood transfusion when compared to shock index unadjusted for age.	Level IV evidence
Biermann, H., Cirone, J., Cone, J. T., Hampton, D. A., Keskey, R. C., Slidell, M. B., Wilson, K. L., Zakrison, T. L.	2021	United States	Retrospective cohort study	In pediatric trauma patients, an Injury Severity Score (ISS) >25 may not accurately predict injury severity. A new model, the Trauma Composite Score (TCS) incorporates age and mechanism of injury, outperforming the ISS in predicting mortality in pediatric patients with blunt trauma.	Level IV evidence
Acker, S. N., Barnett, C. C., Bensard, D. D., Bredbeck, B., Kulungowski, A. M., Partrick, A. A.	2017	United States	Retrospective cohort study	An elevated SIPA score was more effective than age adjusted hypotension in identifying severe traumatic injury likely resulting in blood transfusion, intubation, or emergency surgery.	Level IV evidence
Caupp, S., Kenney, B., Lu, B., Nuss, K. E., Shen, J., Shi, J., Wang, A., Wheeler, K. K., Xiang, H.	2018	United States	Prognostic study	By weighting the Abbreviated Injury Scale (AIS) from different body systems, the Weighted Injury Severity Score (wISS) was much more accurate in identifying children with severe traumatic injury than the traditional Injury Severity Score alone.	Level IV evidence
Billiar, T. R., Brown, J. B., Gaines, B. A., Gestring, M. L., Leeper, C. M., Peitzman, A. B., Sperry, J. L.	2017	United States	Epidemiologic study	An ISS score >15 typically defines severe injury in adults, however, an ISS score >25 might be necessary in determining severe injury in pediatric patients.	Level III evidence
Abe, T., Gakumazawa, M., Morimura, N., Muguruma, T., Shinohara, M., Takeuchi, I., Toida, C.	2020	Japan	Observational study	The Trauma and Injury Severity Score (TRISS) accurately predicted survival in Japanese pediatric blunt trauma patients, however, there were complications in adopting the TRISS model in very young patients with a high degree of injury.	Level III evidence
Bliss, D. W., Cho, J., Matsushima, K., Miyata, S., Park, H.	2017	United States	Retrospective observational study	Major pediatric trauma cases treated at large volume adult trauma centers had better patient outcomes when compared with lower volume centers.	Level III evidence

Baird, R., Deckelbaum, D. L., Razek, T., Roizblatt, D., Séguin, J., St-Louis, E.	2017	Canada	Qualitative systematic review	A health disparity related to accurate assessment and ability to estimate injury severity exists in low-middle-income countries. A simple scoring system should be created that uses point-of-care data as well as easily accessible materials and equipment.	Level I evidence
Acker, S., Bensard, D., Goldsmith, A., Meier, M., Moulton, S., Phillips, R., Recicar, J., Shirek, G.	2020	United States	Retrospective cohort study	Elevated SIPA values in the prehospital setting and on emergency department arrival are associated with early blood transfusion. Serial SIPA values may assist in the early identification of children with blunt liver or spleen injury who will require a blood transfusion.	Level IV evidence
Bingham, J. R., Connor, J. R., Do, W. S., Eckert, M. J., Escobar, M. A., Horton, J. D., Lammers, D. T., Marenco, C. W., Martin, M. J.	2020	United States	Retrospective cohort study	Reverse shock index multiplied by GCS score more accurately identifies pediatric patients at highest risk of death when compared with SIPA alone, following war zone injuries. These findings may help further refine early risk assessments for patient management and resource allocation in constrained settings.	Level IV evidence
Cheng, F. J., Chiu, I. M., Chuang, P. C., Huang, K. C., Huang, Y. H., Li, C. J.	2021	Taiwan	Retrospective cohort study	An increased SIPA values at 24 h after ICU admission predicted high mortality and bad outcomes. Monitoring the trends in the SIPA could help with prognostication and optimize early management.	Level III evidence
Aden, J. K., Bolstridge, J. Borgman, M. A., Muisyo, T., O'Neil, E. R., Spinella, P. C.	2021	United States	Retrospective cohort study	In this massive cohort of pediatric trauma patients, the BIG score using imputation of missing variables performed similarly to the PELOD, PIM2, and PRISM III, further validating the score as a predictor of mortality.	Level III evidence
Bernardo, E. O., Borgman, M. A., Camazine, M., Colvin,	2019	United States	Retrospective cohort study	The BIG score is accurate in predicting mortality in pediatric trauma patients.	Level I evidence

R., Muisyo, T., Spinella, P. C., Thomas, K. A.					
Allukian, M., Hatchimonji, J. S., Luks, V. L., Nance, G. W., Nance, M. L., Swendiman, R. A.	2022	United States	Retrospective cohort study	Although the ISS predicts mortality well, children have lower mortality than do adults for the same ISS, and therefore, the accepted definition of severe injury is not equivalent between these 2 cohorts. Mortality risk is highly dependent on the specific nature of the injury.	Level III evidence
Huh, Y., Kim, J. H., Ko, Y., Lee, J., Yoon, T. J.	2021	South Korea	Retrospective cohort study	The BIG score can predict mortality with excellent accuracy in normotensive children with trauma.	Level III evidence

Discussion

After analyzing these studies, it's clear that there have been several effective assessments established specifically for pediatric blunt trauma patients. However, at this time, it's unclear which assessment modality is superior in predicting injury severity and mortality. More research needs to be completed directly comparing outcomes to determine which should be implemented into the standard of care. In addition to pediatric specific assessments, there are a few adult trauma assessments that have shown to be effective in children, in certain instances (Toida et al., 2020). A 10 year observational study conducted in Japan assessed the utility of the Trauma and Injury Severity Score (TRISS) in pediatric patients with blunt trauma. TRISS is widely used across the United States, and combines the RTS, ISS, type of trauma (blunt or penetrating), and patient age. The results indicated that TRISS appeared to predict survival accurately, however, there were "several problems in adopting the TRISS methodology for younger patients with higher injury severity" (Toida et al., 2020, p. 2). This data suggests that simplifying modifications made to the current TRISS model could potentially be effective in adults as well as children.

While the assessment itself is an essential aspect of creating positive patient outcomes, there are several other very important factors to consider, such as socioeconomic status and geographic location. As discussed earlier, pediatric patients with blunt trauma are often not able to be immediately treated at PTCs, due to their very limited geographical availability. Therefore, ATCs should be assessed for patient outcomes when it comes to treating children with major injuries. While expertise could be lacking in ATCs, it is important to note that higher volume ATCs are much more successful in preventing mortality in pediatric trauma patients than in lower volume centers (Miyata et al., 2017). Additionally, it is important to note that in low-income, low-resource facilities, there is a "gap in the ability to simply and reliably estimate injury severity in pediatric patients and predict their associated probability of outcomes" (St-Louis et al., 2017, p. 299). This disparity is paramount, as 90% of all childhood injury deaths occur in low-middle-income countries (World Health Organization, 2021).

In conclusion, it is crucial to evaluate the shortcomings of pediatric specific assessment modalities in the instance of blunt trauma to better care for children experiencing a dangerous, life threatening emergency. After reviewing these, it is evident that the search for the most efficacious pediatric trauma assessment continues. This issue warrants further investigation, as limited research comparing the effectiveness and utility of pediatric trauma assessments exists.

References

Acker, S. N., Bredbeck, B., Partrick, D. A., Kulungowski, A. M., Barnett, C. C., & Bensard, D. D. (2017). Shock index, pediatric age-adjusted (SIPA) is more accurate than age-adjusted hypotension for trauma team activation. *Surgery*, *161*(3), 803–807. https://doi.org/10.1016/j.surg.2016.08.050

Acker, S. N., Ross, J. T., Partrick, D. A., Tong, S., & Bensard, D. D. (2015). Pediatric specific shock index accurately identifies severely injured children. *Journal of Pediatric Surgery*, *50*(2), 331–334. https://doi.org/10.1016/j.jpedsurg.2014.08.009

Austin, J. R., Ye, C., Lee, M. O., & Chao, S. D. (2021). Does shock index, pediatric age-adjusted predict mortality by trauma center type? *Journal of Trauma and Acute Care Surgery*, *91*(4), 649–654. https://doi.org/10.1097/ta.0000000000003197

Avarello, J. T., & Cantor, R. M. (2007). Pediatric major trauma: An approach to evaluation and Management. *Emergency Medicine Clinics of North America*, *25*(3), 803–836. https://doi.org/10.1016/j.emc.2007.06.013

Bolstridge, J., O'Neil, E. R., Aden, J. K., Muisyo, T., Spinella, P. C., & Borgman, M. A. (2021). Use of the BIG score to predict mortality in pediatric trauma. *The American journal of emergency medicine*, *45*, 472–475. https://doi.org/10.1016/j.ajem.2020.09.060

Brown, J. B., Gestring, M. L., Leeper, C. M., Sperry, J. L., Peitzman, A. B., Billiar, T. R.,
& Gaines, B. A. (2017). The value of the injury severity score in pediatric trauma.
Journal of Trauma and Acute Care Surgery, *82*(6), 995–1001.
https://doi.org/10.1097/ta.0000000000001440

Committee on Trauma. (2016). *NTDB Pediatric annual report 2016* . Fellow of the
American College of Surgeons. Retrieved from
https://www.facs.org/~/media/files/quality%20programs/trauma/ntdb/ntdb%20pedia
tric%20annual%20report%202016.ashx

Davis, A. L., Wales, P. W., Malik, T., Stephens, D., Razik, F., & Schuh, S. (2015). The big
score and prediction of mortality in pediatric blunt trauma. *The Journal of Pediatrics*,
167(3), 593–598. https://doi.org/10.1016/j.jpeds.2015.05.041

Grandjean-Blanchet, C., Emeriaud, G., Beaudin, M., & Gravel, J. (2018). Retrospective
evaluation of the big score to predict mortality in pediatric blunt trauma. *Canadian
Journal of Emergency Medicine*, *20*(4), 592–599.
https://doi.org/10.1017/cem.2017.379

Hatchimonji, J. S., Luks, V. L., Swendiman, R. A., Allukian, M., III, Nance, M. L., Nace,
G. W., Jr, & Allukian, M., 3rd. (2022). Settling the score: Injury severity score fails
to capture nuances in pediatric trauma. *Pediatric Emergency Care*, *38*(2), e828–e832.
https://doi.org/10.1097/PEC.0000000000002363

Huang, K. C., Yang, Y., Li, C. J., Cheng, F. J., Huang, Y. H., Chuang, P. C., & Chiu, I. M.
(2021). Shock Index, pediatric age-adjusted predicts morbidity and mortality in
children admitted to the intensive care unit. *Frontiers in pediatrics*, *9*..
https://doi.org/10.3389/fped.2021.727466

Keskey, R. C., Hampton, D. A., Biermann, H., Cirone, J., Zakrison, T. L., Cone, J. T.,
Wilson, K. L., & Slidell, M. B. (2021). Novel trauma composite score is a more
reliable predictor of mortality than injury severity score in pediatric trauma. *Journal
of Trauma and Acute Care Surgery*, *91*(4), 599–604.
https://doi.org/10.1097/ta.0000000000003235

Koch, E., Lovett, S., Nghiem, T., Riggs, R. A., & Rech, M. A. (2019). Shock index in the
emergency department: utility and limitations. *Open access emergency medicine:
OAEM*, *11*, 179–199. https://doi.org/10.2147/OAEM.S178358

Lammers, D. T., Marenco, C. W., Do, W. S., Conner, J. R., Horton, J. D., Martin, M. J.,
Escobar, M. A., Bingham, J. R., & Eckert, M. J. (2021). Pediatric adjusted reverse
shock index multiplied by Glasgow Coma Scale as a prospective predictor for
mortality in pediatric trauma. *Journal of Trauma and Acute Care Surgery*, *90*(1),
21–26. https://doi.org/10.1097/ta.0000000000002946

Lammers, D. T., Marenco, C. W., Morte, K. R., Conner, J. R., Horton, J. D., Barlow, M.,
Martin, M. J., Bingham, J. R., Eckert, M. J., & Escobar, M. A. (2021). Addition of
neurological status to pediatric adjusted shock index to predict early mortality in

trauma: A pediatric trauma quality improvement program analysis. *Journal of Trauma and Acute Care Surgery*, *91*(4), 584–589. https://doi.org/10.1097/ta.0000000000003204

McFadyen, J. G., Ramaiah, R., & Bhananker, S. M. (2012). Initial assessment and management of pediatric trauma patients. *International Journal of Critical Illness and Injury Science*, *2*(3), 121–127. https://doi.org/10.4103/2229-5151.100888

Miyata, S., Cho, J., Park, H., Matsushima, K., & Bliss, D. W. (2017). Comparison of outcomes in severe pediatric trauma at adult trauma centers with different trauma case volumes. *Journal of Pediatric Surgery*, *52*(11), 1831–1835. https://doi.org/10.1016/j.jpedsurg.2017.01.066

Muisyo, T., Bernardo, E. O., Camazine, M., Colvin, R., Thomas, K. A., Borgman, M. A., & Spinella, P. C. (2019). Mortality prediction in pediatric trauma. *Journal of pediatric surgery*, *54*(8), 1613–1616. https://doi.org/10.1016/j.jpedsurg.2018.08.045

Phillips, R., Acker, S., Shahi, N., Shirek, G., Meier, M., Goldsmith, A., Recicar, J., Moulton, S., & Bensard, D. (2020). The shock index, pediatric age-adjusted (SIPA) enhanced: Prehospital and emergency department SIPA values forecast transfusion needs for blunt solid organ injured children. *Surgery*, *168*(4), 690–694. https://doi.org/10.1016/j.surg.2020.04.06

Shi, J., Shen, J., Caupp, S., Wang, A., Nuss, K. E., Kenney, B., Wheeler, K. K., Lu, B., & Xiang, H. (2018). A new weighted injury severity scoring system: Better predictive

power for pediatric trauma mortality. *Journal of Trauma and Acute Care Surgery*, *85*(2), 334–340. https://doi.org/10.1097/ta.0000000000001943

St-Louis, E., Séguin, J., Roizblatt, D., Deckelbaum, D. L., Baird, R., & Razek, T. (2016). Systematic review and need assessment of pediatric trauma outcome benchmarking tools for low-resource settings. *Pediatric Surgery International*, *33*(3), 299–309. https://doi.org/10.1007/s00383-016-4024-9

Strutt, J., Flood, A., & Kharbanda, A. B. (2019). Shock index as a predictor of morbidity and mortality in pediatric trauma patients. *Pediatric Emergency Care*, *35*(2), 132–137. https://doi.org/10.1097/pec.0000000000001733

Toida, C., Muguruma, T., Gakumazawa, M., Shinohara, M., Abe, T., Takeuchi, I., & Morimura, N. (2020). 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. *BMC Emergency Medicine*, *20*(1). https://doi.org/10.1186/s12873-020-00385-0

World Health Organization. (2021). *Injuries and violence.* https://www.who.int/news-room/fact-sheets/detail/injuries-and-violence

Yoon, T. J., Ko, Y., Lee, J., Huh, Y., & Kim, J. H. (2021). Performance of the BIG score in predicting mortality in normotensive children with trauma. *Pediatric Emergency Care*, *37*(12), e1582–e1588. https://doi.org/10.1097/PEC.0000000000002122