Trauma Surgery & Acute Care Open

# Who will be the bastions of pediatric trauma care?

Melike Harfouche ,[1,2] Kelsey Higgins,[2] Elizabeth Waibel,[3] Mark B Slidell,[4] Isam Nasr,[4] Gary W Nace,[5] David Efron[1,2]

[1]Department of Surgery, University of Maryland School of Medicine, Baltimore, Maryland, USA
[2]University of Maryland Medical Center, Baltimore, Maryland, USA
[3]Children's National Hospital, Washington, District of Columbia, USA
[4]Johns Hopkins School of Medicine, Baltimore, Maryland, USA
[5]Children's Hospital of Philadelphia, Philadelphia, Pennsylvania, USA

**Correspondence to**
Dr Melike Harfouche; mharfouche@som.umaryland.edu

Received 26 July 2024
Accepted 5 December 2024



**To cite:** Harfouche M, Higgins K, Waibel E, *et al*. *Trauma Surg Acute Care Open* 2025;**10**:e001573.

## SUMMARY

The 2024 American College of Surgeons Point Counterpoint conference held in Baltimore, Maryland included a panel on pediatric trauma. The panelists included pediatric surgeons, a pediatric trauma nurse practitioner, a trauma pharmacist and a trauma surgeon. The discussion focused on unique clinical considerations for pediatric abdominal trauma, pharmacologic best practices and optimizing care models to incorporate pediatric and trauma surgeons. Points raised during panel discussion will be highlighted and expanded on in the following article, which is by no means meant to be a comprehensive review of pediatric trauma management but rather a discussion of important topics within the field.

## CLINICAL CONSIDERATIONS FOR PEDIATRIC ABDOMINAL TRAUMA

The panelists brought up key considerations for the initial assessment of pediatric trauma patients that differ from the management of adult trauma patients. This included the limited utility of the Focused Assessment for the Sonography of Trauma (FAST) exam, the importance of laboratory markers in dictating further workup and limiting use of computed tomography (CT) imaging, and differences in approach to the management of solid organ injury.

The FAST exam is a cornerstone in the evaluation of the hypotensive adult blunt trauma patient and is crucial to determining whether to proceed to the operating room if a source of intraperitoneal bleeding or cardiac tamponade is identified. The FAST exam was popularized as a surgeon-performed diagnostic tool for the assessment of trauma patients in the early 1990s.[1] It continues to be widely used in adult trauma centers and taught during the Advanced Trauma Life Support course sponsored by the American College of Surgeons. After validating its use in adult patients, Rozycki *et al* evaluated its utility in pediatric patients <15 years of age in 1998.[2] Out of 192 individuals, the sensitivity and specificity of the FAST exam were found to be 80% and 100%, respectively. Neither of the two individuals who had a false negative required operative intervention. More recent data, however, suggest that the utility of the FAST exam in pediatric trauma is limited.[3] A randomized clinical trial by Holmes *et al* found that the use of FAST in hemodynamically stable blunt trauma patients <18 years old as compared with standard of care without FAST did not reduce the rate of CT use nor positively influence any other outcomes of interest such as missed intra-abdominal injuries, hospital charges or length of stay.[4] A systematic review published in 2021 found that the FAST exam rarely altered the management of the hemodynamically stable pediatric trauma patient.[5] A study by Calder *et al* that included both hemodynamically stable and unstable pediatric trauma patients found highly variable use of FAST for blunt pediatric trauma (<16 years old) across 14 US level I trauma centers, which ranged between 0.8% and 94%.[6] Their main conclusion was that the FAST exam had low sensitivity for detecting intrabdominal injury (IAI) overall and for IAI requiring intervention. This study is listed as part of the guidelines published by the Pediatric Trauma Society, which recommends that the FAST be used with caution as a method for detecting abdominal injury.[7] Overall, members of the panel echoed these studies by stating they did not routinely use FAST in their care of pediatric trauma patients.

Whereas high-definition axial imaging has become ubiquitous in the evaluation of adult blunt abdominal trauma (BAT), laboratory testing has traditionally been the gatekeeper to proceeding with abdominopelvic CT in pediatric trauma patients. The data to support this practice, however, are highly conflicting, leading to a heterogeneous practice pattern across centers that treat pediatric trauma patients. A study of 14 different pediatric level I trauma centers found large variability in laboratory tests that were ordered across centers and weak correlation between laboratory results and CT use.[8] The American College of Surgeons Trauma Quality Improvement Program Best Practices Guidelines in Imaging recommends screening laboratory tests prior to withholding abdominal CT imaging in children.[9] Another study published in the American Journal of Emergency Medicine evaluated the role of laboratory markers in predicting injury among children <18 years who sustained BAT.[10] Among 327 patients, they found significantly higher mean transaminase and lipase values for those with solid organ injury, but most were still within normal range. They recommended that laboratory tests alone should not be used to screen pediatric patients with BAT. A prudent approach to avoiding CT imaging in injured children involves a combination of negative clinical, radiographic and laboratory findings, as each in isolation may not reliably rule out IAI. One study out of Memphis found that combining negative transaminase results with a negative FAST increased negative predictive value for IAI from 83% to 96% when compared with using each modality alone.[11] A multicenter study involving 14 level I pediatric trauma centers used prospective data to develop a prediction rule

that used a combination of history, physical exam findings, chest X-ray and liver and pancreatic enzyme levels. Its negative predictive value for identifying IAI requiring intervention was 100%, which was confirmed in a validation study published a year later.[12 13] The Pediatric Emergency Care Research Network has developed clinical guidelines based on these study findings that combine clinical and laboratory features to identify individuals at high risk for BAT to reduce unnecessary imaging.[14 15]

Another topic covered by the panel was key differences in the management of solid organ injury between pediatric and adult patients. In some cases, these differences emanate from anatomic changes that occur within the body as it ages. The pediatric spleen, for instance, has a much thicker capsule and firmer parenchyma than the adult spleen. When compounded with the larger risk of postsplenectomy sepsis in children less than 5 years of age, most traumatologists will have a much higher threshold to perform a splenectomy on a pediatric patient with the same splenic grade of injury as an adult.[16] In fact, pediatric centers have led the charge in non-operative management of splenic injuries, demonstrating high splenic salvage rates for injuries that were previously deemed operative. This is likely due to a greater reliance on hemodynamic status as the indication for splenectomy rather than the extent of injury seen on CT. One study from Delaware showed a reduction in the rate of pediatric splenectomy from 11% to 2.7% (p=0.012) after the addition of a verified pediatric trauma center.[17] Reports of non-operative management of splenic injury in children can be found as early as the 1970s[18 19]. Given the greater resilience of the pediatric spleen to injury, the decision to proceed with splenic angioembolization (SAE) over observation is also made cautiously, as there is risk to any procedure and most pediatric splenic injuries will heal without intervention. The relative novelty of angioembolization of solid organ injury as compared with surgical intervention has led to less certainty regarding the management of both adult and pediatric trauma when it comes to the use of interventional techniques. A study of adult versus pediatric trauma centers using the National Trauma Data Bank found that pediatric trauma centers performed fewer SAE procedures on pediatric patients with similar splenic salvage rates to adult centers.[20] A recent evaluation of 10 level I pediatric trauma centers found that angioembolization of splenic or liver injuries was performed rarely and usually in a delayed fashion, but nonetheless associated with 100% splenic salvage rates.[21] The 2023 American Pediatric Surgical Association guidelines contrast starkly with adult guidelines and state that angioembolization of liver or spleen injuries should only be performed for patients with evidence of ongoing bleeding and recommend against prophylactic angioembolization.[22] Further research is needed to evaluate and justify the discordance in management of solid organ injury between adults and children.[23]

## PEDIATRIC PHARMACOLOGY

There is great variation in pediatric drug pharmacokinetics across subpopulations, unlike adults who have a relatively predictable weight-based drug distribution. Body surface area, proportion of body water to fat, hepatic and renal clearance and pharmacologic receptor functions undergo significant changes as an infant grows into a toddler and then an adolescent.[24]

The study of pediatric pharmacology was limited by the Food and Drug Administration until the 1970s due to ethical concerns, resulting in a more basic understanding of drug dosing considerations for pediatric patients when compared with adults.[24] For example, while tranexamic acid has a plethora of literature characterizing the optimal adult patient population to benefit from the medication, there is far less literature in pediatric patients, and the optimal dose is unknown.[25]

One study evaluating prescription errors in nine pediatric intensive care units, which is a relatively controlled setting when compared with the trauma bay, found the error rate to be 11%.[26] The treatment of pediatric patients at adult trauma centers can lead to these medication errors due to inexperience with pediatric trauma dose adjustments, drug preparation and administration. Adult teams are often inexperienced with the dose adjustments required outside of the standard weight-based approach. A study looking at the use of the Broselow tape in estimating pediatric weight at a rural level I trauma center found that in close to half of patients, the weight was underestimated.[27] This led to underdosing of many medications and blood transfusions. The growing obesity epidemic may make the use of Broselow tape more and more unreliable. Drug preparation at the bedside of any trauma patient can also lead to medication errors, but especially in pediatric patients where often doses must be prepared by removing drugs from existing adult concentrations and volumes.

With these considerations in mind, the panelists emphasized the importance of multidisciplinary teams and pediatric specialists at trauma centers that treat a young population to avoid medication errors. The addition of a pediatric pharmacist to a multidisciplinary group of experts can improve care not only through their expertise but also through the development of guidelines and team education. A study conducted at a level I trauma center that developed a multidisciplinary team consisting of a pediatric hospitalist, a pediatric care coordinator, pediatric nurse, pharmacist, and the trauma service was able to reduce medication errors by 40%.[28] Incorporating specialized roles with pediatric expertise within a trauma service will improve pediatric trauma care.

## OPTIMIZING CARE MODELS

Although we can all agree that the ideal team to care for a pediatric trauma patient would include both adult and pediatric trauma surgeons, there are too few of each in the USA to staff all hospitals where these patients are treated. The question then becomes, given limitations in resources, how do we ensure that pediatric trauma patients receive timely and effective care? One of the first steps is the existence of a regional trauma system that can transport injured children to facilities that have the appropriate resources to care for them. Some of these facilities may not be verified pediatric trauma centers but must be equipped to provide care to pediatric patients. A recent publication from the Government Accountability Office states that 43% of children in the USA live over 30 miles from a high-level pediatric trauma center that can treat all severity of injuries.[29] A separate study found that 17 million children do not live within 60 min of a pediatric trauma center.[30] These deficiencies in access to any pediatric trauma care make it essential that staff at non-pediatric facilities, including verified adult trauma centers, are appropriately trained in resuscitation and stabilization of critically injured children. This process can include the development of local pediatric trauma policies and periodic training of nursing and physician staff. Given the rarity of pediatric trauma treated at these centers, high-fidelity simulation may be a valuable training tool. There must then be a clear process in place for transfer of these critically ill patients to pediatric trauma centers, where they will receive appropriate pediatric intensive care and age-specific rehabilitation and ancillary services.

## CONCLUSIONS

The answer to the question posed in the title of this article, 'Who will be the bastions of pediatric trauma care' is now clear: it must be the entire medical community. It is essential that healthcare staff be appropriately trained and provided with the right resources along the entire continuum of care of the pediatric trauma patient. Emergency medical staff must transport patients to the right facilities at the right time and these facilities must be knowledgeable on the latest guidelines for pediatric trauma care, including an appreciation of the key differences in the treatment of pediatric versus adult patients. As the scientific community continues to grow our understanding of these differences, we must work together as a medical community of emergency medical staff, nurses, physicians and pharmacists to reduce the burden of pediatric trauma morbidity and mortality.

**X** Melike Harfouche @melikeharfouche

**Contributors** MH is the guarantor. All authors contributed to the writing and editing of the manuscript.

**Funding** The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

**Competing interests** None declared.

**Patient consent for publication** Not applicable.

**Ethics approval** Not applicable.

**Provenance and peer review** Not commissioned; internally peer-reviewed.



**ORCID iD**

Melike Harfouche http://orcid.org/0000-0001-9555-5698

## REFERENCES

1 Rozycki GS, Ochsner MG, Schmidt JA, Frankel HL, Davis TP, Wang D, Champion HR. A prospective study of surgeon-performed ultrasound as the primary adjuvant modality for injured patient assessment. *J Trauma* 1995;39:492–8;
2 Thourani VH, Pettitt BJ, Schmidt JA, Cooper WA, Rozycki GS. Validation of surgeon-performed emergency abdominal ultrasonography in pediatric trauma patients. *J Pediatr Surg* 1998;33:322–8.
3 Kessler DO. Abdominal Ultrasound for Pediatric Blunt Trauma: FAST Is Not Always Better. *JAMA* 2017;317:2283–5.
4 Holmes JF, Kelley KM, Wootton-Gorges SL, Utter GH, Abramson LP, Rose JS, Tancredi DJ, Kuppermann N. Effect of Abdominal Ultrasound on Clinical Care, Outcomes, and Resource Use Among Children With Blunt Torso Trauma: A Randomized Clinical Trial. *JAMA* 2017;317:2290–6.
5 Liang T, Roseman E, Gao M, Sinert R. The Utility of the Focused Assessment With Sonography in Trauma Examination in Pediatric Blunt Abdominal Trauma: A Systematic Review and Meta-Analysis. *Pediatr Emerg Care* 2021;37:108–18.
6 Calder BW, Vogel AM, Zhang J, Mauldin PD, Huang EY, Savoie KB, Santore MT, Tsao K, Ostovar-Kermani TG, Falcone RA, *et al*. Focused assessment with sonography for trauma in children after blunt abdominal trauma: A multi-institutional analysis. *J Trauma Acute Care Surg* 2017;83:218–24.
7 PTS - pts guidelines hub. Available: https://pediatrictraumasociety.org/resources/guidelines/?s=section&sID=abdomen#a1 [Accessed 23 Jul 2024].
8 Vogel AM, Zhang J, Mauldin PD, Williams RF, Huang EY, Santore MT, Tsao K, Falcone RA, Dassinger MS, Haynes JH, *et al*. Variability in the evalution of pediatric blunt abdominal trauma. *Pediatr Surg Int* 2019;35:479–85.
9 ACS tqip best practices guidelines in imaging. 2018. Available: https://www.facs.org/media/oxdjw5zj/imaging_guidelines.pdf
10 Kuas C, Acar N, Ozakin E, Karakilic E, Arda MS, Bastug BT, Yuksel GC, Canakci ME. The diagnostic value of laboratory tests in detecting solid organ injuries in pediatric patients with blunt abdominal trauma. *Am J Emerg Med* 2022;57:133–7.
11 Sola JE, Cheung MC, Yang R, Koslow S, Lanuti E, Seaver C, Neville HL, Schulman CI. Pediatric FAST and elevated liver transaminases: An effective screening tool in blunt abdominal trauma. *J Surg Res* 2009;157:103–7.
12 Streck CJ, Vogel AM, Zhang J, Huang EY, Santore MT, Tsao K, Falcone RA, Dassinger MS, Russell RT, Blakely ML, *et al*. Identifying Children at Very Low Risk for Blunt Intra-Abdominal Injury in Whom CT of the Abdomen Can Be Avoided Safely. *J Am Coll Surg* 2017;224:449–58.
13 Arbra CA, Vogel AM, Plumblee L, Zhang J, Mauldin PD, Dassinger MS, Russell RT, Blakely ML, Streck CJ. External validation of a five-variable clinical prediction rule for identifying children at very low risk for intra-abdominal injury after blunt abdominal trauma. *J Trauma Acute Care Surg* 2018;85:71–7.
14 Holmes JF, Mao A, Awasthi S, McGahan JP, Wisner DH, Kuppermann N. Validation of a prediction rule for the identification of children with intra-abdominal injuries after blunt torso trauma. *Ann Emerg Med* 2009;54:528–33.
15 McGrew PR, Chestovich PJ, Fisher JD, Kuhls DA, Fraser DR, Patel PP, Katona CW, Saquib S, Fildes JJ. Implementation of a CT scan practice guideline for pediatric trauma patients reduces unnecessary scans without impacting outcomes. *J Trauma Acute Care Surg* 2018;85:451–8.
16 Coccolini F, Montori G, Catena F, Kluger Y, Biffl W, Moore EE, Reva V, Bing C, Bala M, Fugazzola P, *et al*. Splenic trauma: WSES classification and guidelines for adult and pediatric patients. *World J Emerg Surg* 2017;12:40.
17 Murphy EEK, Murphy SG, Cipolle MD, Tinkoff GH. The pediatric trauma center and the inclusive trauma system: Impact on splenectomy rates. *J Trauma Acute Care Surg* 2015;78:930–3;
18 Aronson DZ, Scherz AW, Einhorn AH, Becker JM, Schneider KM. Nonoperative management of splenic trauma in children: a report of six consecutive cases. *Pediatrics* 1977;60:482–5.
19 Joseph TP, Wyllie GG, Savage JP. The non-operative management of splenic trauma. *Aust N Z J Surg* 1977;47:179–82.
20 Swendiman RA, Abramov A, Fenton SJ, Russell KW, Nance ML, Nace Jr. GW, Iii MA. Use of angioembolization in pediatric polytrauma patients. *J Pediatr Surg* 2021;56:2045–51.
21 Naiditch JA, Notrica DM, Sayrs LW, Linnaus M, Stottlemyre R, Garcia NM, Lawson KA, Cohen AS, Letton RW, Johnson J, *et al*. The use and timing of angioembolization in pediatric blunt liver and spleen injury. *J Trauma Acute Care Surg* 2024;96:915–20.
22 Williams RF, Grewal H, Jamshidi R, Naik-Mathuria B, Price M, Russell RT, Vogel A, Notrica DM, Stylianos S, Petty J. Updated APSA Guidelines for the Management of Blunt Liver and Spleen Injuries. *J Pediatr Surg* 2023;58:1411–8.
23 Stylianos S. Evidence-based guidelines for resource utilization in children with isolated spleen or liver injury. The APSA Trauma Committee. *J Pediatr Surg* 2000;35:164–7;
24 Lu H, Rosenbaum S. Developmental pharmacokinetics in pediatric populations. *J Pediatr Pharmacol Ther* 2014;19:262–76.
25 Hamele M, Aden JK, Borgman MA. Tranexamic acid in pediatric combat trauma requiring massive transfusions and mortality. *J Trauma Acute Care Surg* 2020;89:S242–5.
26 Cimino MA, Kirschbaum MS, Brodsky L, Shaha SH, Child Health Accountability Initiative. Assessing medication prescribing errors in pediatric intensive care units. *Pediatr Crit Care Med* 2004;5:124–32.
27 Knight JC, Nazim M, Riggs D, Channel J, Mullet C, Vaughan R, Wilson A. Is the Broselow tape a reliable indicator for use in all pediatric trauma patients?: A look at a rural trauma center. *Pediatr Emerg Care* 2011;27:479–82.
28 Kalina M, Tinkoff G, Gleason W, Veneri P, Fulda G. A multidisciplinary approach to adverse drug events in pediatric trauma patients in an adult trauma center. *Pediatr Emerg Care* 2009;25:444–6.
29 Office USGA. Pediatric trauma centers: availability, outcomes, and federal support related to pediatric trauma care |U.S. GAO. Available: https://www.gao.gov/products/gao-17-334 [Accessed 24 Jul 2024].
30 Shook JE, *et al*, Committee on Pediatric Emergency Medicine COI, Violence App Section on Critical Care, Section on Orthopaedics, Section on Surgery, Section on Transport Medicine, and Society of Trauma Nurses Pediatric Committee. Management of Pediatric Trauma. *Pediatrics* 2016;138:e20161569.