

# Multisystem Trauma

## EVIDENCE REPOSITORIES

Evidence repositories are collections of best available resources and evidence (clinical guidelines, peer reviewed literature, systematic reviews, etc.), collated by our knowledge synthesis team and content advisors. This evidence repository is not intended to be an exhaustive list of resources for a topic, but rather a curated list of current, evidence-based resources, based on expert consensus of relevance and usability for a general emergency department setting. We search databases (Cochrane Library, PubMed, TRIP Database) and web search engines (Google, Google Scholar) to locate evidence. Additionally, hospital websites are browsed for guidance documents, such as clinical practice guidelines (CPG) for healthcare professionals.

Every effort is made to identify resources that are open access (i.e. publicly available, free of charge, not requiring a subscription).

More information about the creation of our evidence repositories can be found at <https://pubmed.ncbi.nlm.nih.gov/28537762/>

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TREKK developed resources for healthcare providers and parents & families can be found [here](#).

## Clinical Guidelines

1. Coccolini F, Coimbra R, Ordonez C, et al. [Liver trauma: WSES 2020 guidelines](#). World J Emerg Surg. 2020;15(24).
2. Spahn DR, Bouillon B, Cerny V, et al. [The European guideline on management of major bleeding and coagulopathy following trauma: fifth edition](#). Crit Care. 2019;23(1):98.
3. Pediatric Trauma Society. [Pediatric Trauma Society Clinical Practice Guidelines](#). 2019.
4. Herman MJ, Brown KO, Sponseller PD, et al. [Pediatric Cervical Spine Clearance: A Consensus Statement and Algorithm from the Pediatric Cervical Spine Clearance Working Group](#). J Bone Joint Surg Am. 2019;101(1):e1.
5. Galvagno SM, Jr., Nahmias JT, Young DA. [Advanced Trauma Life Support\(®\) Update 2019: Management and Applications for Adults and Special Populations](#). Anesthesiol Clin. 2019;37(1):13-32.
6. American College of Radiology. [ACR Appropriateness Criteria: Suspected Spine Trauma](#) [see section "Pediatric Patients" starting page 12]. 2018.
7. National Cancer Institute. [Radiation Risks and Pediatric Computed Tomography \(CT\): A Guide for Health Care Providers](#). 2018.
8. Fischer PE, Perina DG, Delbridge TR, et al. [Spinal Motion Restriction in the Trauma Patient - A Joint Position Statement](#). Prehosp Emerg Care. 2018;22(6):659-61.
9. Chung S, Mikrogianakis A, Wales PW, et al. [Trauma association of Canada Pediatric Subcommittee National Pediatric Cervical Spine Evaluation Pathway: consensus guidelines](#). J Trauma. 2011;70(4):873-84.

## Summaries of Systematic Reviews

1. Brand M, Grieve A. [Prophylactic antibiotics for penetrating abdominal trauma](#). Cochrane Database Syst Rev. 2019.
2. Haugaard MV, Wettergren A, Hillings JG, et al. [Prophylactic antibiotics for penetrating abdominal trauma](#). Cochrane Database Syst Rev. 2014.

## Systematic Reviews

1. Letica-Kriegel AS, Kaplan A, Orlas C, Masiakos PT. [Variability of Pediatric Cervical Spine Clearance Protocols: A Systematic Review](#). Ann Surg. 2022;276(6):989-94.
2. Gianola S, Castellini G, Biffi A, Porcu G, Napoletano A, Coclite D, et al. [Accuracy of risk tools to predict critical bleeding in major trauma: A systematic review with meta-analysis](#). J Trauma Acute Care Surg. 2022;92(6):1086-96.
3. Ekhtor C, Nwankwo I, Nicol A. Implementation of National Emergency X-Radiography Utilization Study (NEXUS) Criteria in Pediatrics: A Systematic Review. Cureus. 2022;14(10):e30065. <https://pubmed.ncbi.nlm.nih.gov/36238421/>.

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4. Cheung R, Shukla M, Akers KG, Farooqi A, Sethuraman U. [Bicycle handlebar injuries - a systematic review of pediatric chest and abdominal injuries](#). *Am J Emerg Med*. 2022;51:13-21.
5. Mora MC, Veras L, Burke RV, Cassidy LD, Christopherson N, Cunningham A, et al. [Pediatric trauma triage: A Pediatric Trauma Society Research Committee systematic review](#). *J Trauma Acute Care Surg*. 2020;89(4):623-30.
6. Gates RL, Price M, Cameron DB, Somme S, Ricca R, Oyetunji TA, et al. [Non-operative management of solid organ injuries in children: An American Pediatric Surgical Association Outcomes and Evidence Based Practice Committee systematic review](#). *J Pediatr Surg*. 2019;54(8):1519-26.
7. Stengel D LJ, Ferrada P, Ekkernkamp A, Mutze S, Hoenning A. [Point-of-care ultrasonography for diagnosing thoracoabdominal injuries in patients with blunt trauma](#). *Cochrane Database of Systematic Reviews*. 2018;Art. No.: CD012669(12).
8. Maw G, Furyk C. [Pediatric Massive Transfusion: A Systematic Review](#). *Pediatr Emerg Care*. 2018;34(8):594-8.
9. Chin K, Abzug J, Bae DS, Horn BD, Herman M, Ebersson CP. [Avoiding Errors in the Management of Pediatric Polytrauma Patients](#). *Instr Course Lect*. 2016;65:345-52.
10. Ker K, Roberts I, Shakur H, Coats TJ. [Antifibrinolytic drugs for acute traumatic injury](#). *Cochrane Database Syst Rev*. 2015(5):Cd004896.
11. Van Vugt R, Keus F, Kool D, Deunk J, Edwards M. [Selective computed tomography \(CT\) versus routine thoracoabdominal CT for high-energy blunt-trauma patients](#). *Cochrane Database Syst Rev*. 2013;2013(12):Cd009743.
12. Stengel D, Bauwens K, Rademacher G, Ekkernkamp A, Güthoff C. [Emergency ultrasound-based algorithms for diagnosing blunt abdominal trauma](#). *Cochrane Database Syst Rev*. 2013(7):Cd004446.
13. Barrera LM, Perel P, Ker K, Ciocchi R, Farinella E, Morales Uribe CH. [Thromboprophylaxis for trauma patients](#). *Cochrane Database Syst Rev*. 2013(3):Cd008303.

## Key Studies

### *Multisystem trauma*

1. Pariaszevski A, Wang NE, Lee MO, Brown I, Imler D, Lowe J, Fang A. [Computed tomography rates in pediatric trauma patients among emergency medicine and pediatric emergency medicine physicians](#). *J Pediatr Surg*. 2023 Feb;58(2):315-319.
2. Lee LK, Porter JJ, Mannix R, Rees CA, Schutzman SA, Fleegler EW, Farrell CA. [Pediatric traumatic injury emergency department visits and management in US children's hospitals from 2010 to 2019](#). *Ann Emerg Med*. 2022 Mar;79(3):279-287.
3. Strait L, Sussman R, Ata A, et al. [Utilization of CT imaging in minor pediatric head, thoracic, and abdominal trauma in the United States](#). *J Pediatr Surg*. 2020 Sep;55(9):1766-1772.
4. Meltzer JA, Stone ME Jr, Reddy SH, et al. [Association of whole-body computed tomography with mortality risk in children with blunt trauma](#). *JAMA Pediatr*. 2018 Jun 1;172(6):542-549.
5. Patel SC, Murphy S, Penfil S, et al. [Impact of Interfacility Transport Method and Specialty Teams on Outcomes of Pediatric Trauma Patients](#). *Pediatr Emerg Care*. 2018 Jul;34(7):467-472.

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6. Hicks C, Petrosoniak A. [The human factor: optimizing trauma team performance in dynamic clinical environments](#). *Emerg Med Clin North Am*. 2018 Feb;36(1):1-17.
7. O'Connell K, Fritzeen J, Guzzetta CE, et al. [Family presence during trauma resuscitation: family members' attitudes, behaviors, and experiences](#). *Am J Crit Care*. 2017 May;26(3):229-239.
8. Hewes HA, Christensen M, Taillac PP, et al. [Consequences of pediatric undertriage and overtriage in a statewide trauma system](#). *J Trauma Acute Care Surg*. 2017 Oct;83(4):662-667.
9. O'Connell KJ, Carter EA, Fritzeen JL, et al. [Effect of family presence on advanced trauma life support task performance during pediatric trauma team evaluation](#). *Pediatr Emerg Care*. 2017 May 8.
10. Lerner EB, Drendel AL, Cushman JT, et al. [Ability of the physiologic criteria of the field triage guidelines to identify children who need the resources of a trauma center](#). *Prehosp Emerg Care*. 2017 Mar-Apr;21(2):180-184.
11. Davis AL, Wales PW, Malik T, et al. [The BIG score and prediction of mortality in pediatric blunt trauma](#). *J Pediatr*. 2015 Sep;167(3):593-8.e1.
12. Lyon RM, Perkins ZB, Chatterjee D, et al; Kent, Surrey & Sussex Air Ambulance Trust. [Significant modification of traditional rapid sequence induction improves safety and effectiveness of pre-hospital trauma anaesthesia](#). *Crit Care*. 2015 Apr 1;19(1):134.
13. Ballow SL, Kaups KL, Anderson S, et al. [A standardized rapid sequence intubation protocol facilitates airway management in critically injured patients](#). *J Trauma Acute Care Surg*. 2012 Dec;73(6):1401-5.

## ***Cervical spine trauma and spinal motion restriction***

1. Sharma B, Kolousek A, Lian B, Koganti D, Smith RN, Sola R Jr. [Cervical spine computed tomography in adolescent blunt trauma patients: Are they being overutilized?](#) *J Surg Res*. 2023 Feb;282:155-159.
2. Hewes HA, Ravindra VM, Ryan S, Russell KW, Soisson S, Brockmeyer DL. [The fate of the cervical collar: An observational pilot study investigating follow-up care after emergency department discharge in children with mild traumatic neck injuries](#). *Pediatr Emerg Care*. 2022 May 25.
3. Schonenberg Llach M, Fische JN, Yorkgitis BK. [Implementation of a dual cervical spine and blunt cerebrovascular injury assessment pathway for pediatric trauma patients](#). *Am J Emerg Med*. 2021 Sep;47:74-79.
4. Leonard JC, Browne LR, Ahmad FA, et al. [Cervical spine injury risk factors in children with blunt trauma](#). *Pediatrics*. 2019 Jul;144(1):e20183221.
5. Arbuthnot M, Mooney DP. [The sensitivity and negative predictive value of a pediatric cervical spine clearance algorithm that minimizes computerized tomography](#). *J Pediatr Surg*. 2017 Jan;52(1):130-135.
6. Hale DF, Fitzpatrick CM, Doski JJ, et al. [Absence of clinical findings reliably excludes unstable cervical spine injuries in children 5 years or younger](#). *J Trauma Acute Care Surg*. 2015 May;78(5):943-8.
7. Leonard JR, Jaffe DM, Kuppermann N, et al; Pediatric Emergency Care Applied Research Network (PECARN) Cervical Spine Study Group. [Cervical spine injury patterns in children](#). *Pediatrics*. 2014 May;133(5):e1179-88.
8. Kim EG, Brown KM, Leonard JC, et al; C-Spine Study Group of the Pediatric Emergency Care Applied Research Network (PECARN). [Variability of prehospital spinal immobilization in children at risk for cervical spine injury](#). *Pediatr Emerg Care*. 2013 Apr;29(4):413-8.

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9. Leonard JC, Mao J, Jaffe DM. [Potential adverse effects of spinal immobilization in children](#). *Prehosp Emerg Care*. 2012 Oct-Dec;16(4):513-8.
10. Pieretti-Vanmarcke R, Velmahos GC, Nance ML, et al. [Clinical clearance of the cervical spine in blunt trauma patients younger than 3 years: a multi-center study of the American association for the surgery of trauma](#). *J Trauma*. 2009 Sep;67(3):543-9; discussion 549-50.
11. Viccellio P, Simon H, Pressman BD, et al; NEXUS Group. [A prospective multicenter study of cervical spine injury in children](#). *Pediatrics*. 2001 Aug;108(2):E20.

## **Thoracoabdominal and pelvic trauma**

1. Long MK, Vohra MK, Bonnette A, et al. [Focused assessment with sonography for trauma in predicting early surgical intervention in hemodynamically unstable children with blunt abdominal trauma](#). *J Am Coll Emerg Physicians Open*. 2022 Jan 27;3(1):e12650.
2. Polites SF, Moody S, Williams RF, et al. [Timing and volume of crystalloid and blood products in pediatric trauma: An Eastern Association for the Surgery of Trauma multicenter prospective observational study](#). *J Trauma Acute Care Surg*. 2020 Jul;89(1):36-42.
3. Holl EM, Marek AP, Nygaard RM, et al. [Use of chest computed tomography for blunt pediatric chest trauma: does it change clinical course?](#) *Pediatr Emerg Care*. 2020 Feb;36(2):81-86.
4. Galos D, Doering TA. [High-energy fractures of the pelvis and acetabulum in pediatric patients](#). *J Am Acad Orthop Surg*. 2020 May 1;28(9):353-362.
5. Guillaume JM, Pesenti S, Jouve JL, et al. [Pelvic fractures in children \(pelvic ring and acetabulum\)](#). *Orthop Traumatol Surg Res*. 2020 Feb;106(1S):S125-S133.
6. Springer E, Frazier SB, Arnold DH, Vukovic AA. [External validation of a clinical prediction rule for very low risk pediatric blunt abdominal trauma](#). *Am J Emerg Med*. 2019 Sep;37(9):1643-1648.
7. Vandewalle RJ, Barker SJ, Raymond JL, et al. [Pediatric handlebar injuries: more than meets the abdomen](#). *Pediatr Emerg Care*. 2021 Sep 1;37(9):e517-e523.
8. Kundal VK, Debnath PR, Meena AK, et al. [Pediatric thoracoabdominal trauma: experience from a tertiary care center](#). *J Indian Assoc Pediatr Surg*. 2019 Oct-Dec;24(4):264-270.
9. Coccolini F, Moore EE, Kluger Y, et al; WSES-AAST Expert Panel. [Kidney and uro-trauma: WSES-AAST guidelines](#). *World J Emerg Surg*. 2019 Dec 2;14:54.
10. Notrica DM, Sayrs LW, Bhatia A, et al. [The incidence of delayed splenic bleeding in pediatric blunt trauma](#). *J Pediatr Surg*. 2018 Feb;53(2):339-343.
11. Stephens CQ, Boulos MC, Connelly CR, et al. [Limiting thoracic CT: a rule for use during initial pediatric trauma evaluation](#). *J Pediatr Surg*. 2017 Dec;52(12):2031-2037.
12. Streck CJ, Vogel AM, Zhang J, et al; Pediatric Surgery Research Collaborative. [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 Apr;224(4):449-458.e3.
13. Holmes JF, Kelley KM, Wootton-Gorges SL, et al. [Effect of abdominal ultrasound on clinical care, outcomes, and resource use among children with blunt torso trauma: a randomized clinical trial](#). *JAMA*. 2017 Jun 13;317(22):2290-2296.



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14. McNamara C, Mironova I, Lehman E, Olympia RP. [Predictors of intrathoracic injury after blunt torso trauma in children presenting to an emergency department as trauma activations.](#) *J Emerg Med.* 2017 Jun;52(6):793-800.
15. Coccolini F, Montori G, Catena F, et al. [Splenic trauma: WSES classification and guidelines for adult and pediatric patients.](#) *World J Emerg Surg.* 2017 Aug 18;12:40.
16. Hermans E, Cornelisse ST, Biert J, et al. [Paediatric pelvic fractures: how do they differ from adults?](#) *J Child Orthop.* 2017;11(1):49-56.
17. Magoteaux SR, Notrica DM, Langlais CS, et al. [Hypotension and the need for transfusion in pediatric blunt spleen and liver injury: An ATOMAC+ prospective study.](#) *J Pediatr Surg.* 2017 Jun;52(6):979-983.
18. O'Connor SC, Doud AN, Sieren LM, et al. [The spleen not taken: Differences in management and outcomes of blunt splenic injuries in teenagers cared for by adult and pediatric trauma teams in a single institution.](#) *J Trauma Acute Care Surg.* 2017 Sep;83(3):368-372.
19. Snow A, Milliren CE, Graham DA, et al. [Quality of pediatric abdominal CT scans performed at a dedicated children's hospital and its referring institutions: a multifactorial evaluation.](#) *Pediatr Radiol.* 2017 Apr;47(4):391-397.
20. Calder BW, Vogel AM, Zhang J, et al. [Focused assessment with sonography for trauma in children after blunt abdominal trauma: A multi-institutional analysis.](#) *J Trauma Acute Care Surg.* 2017 Aug;83(2):218-224.
21. Golden J, Isani M, Bowling J, et al. [Limiting chest computed tomography in the evaluation of pediatric thoracic trauma.](#) *J Trauma Acute Care Surg.* 2016 Aug;81(2):271-7.
22. Swaid F, Peleg K, Alfici R, Olsha O, Givon A, Kessel B. [Does severity of pelvic fractures correlate with the incidence of associated intra-abdominal injuries in children?](#) *Eur J Pediatr Surg.* 2016 Jun;26(3):287-90.
23. Holscher CM, Faulk LW, Moore EE et al. [Chest computed tomography imaging for blunt pediatric trauma: not worth the radiation risk.](#) *J Surg Res.* 2013 Sep;184(1):352-7.
24. Holmes JF, Lillis K, Monroe D, et al; Pediatric Emergency Care Applied Research Network (PECARN). [Identifying children at very low risk of clinically important blunt abdominal injuries.](#) *Ann Emerg Med.* 2013 Aug;62(2):107-116.e2.
25. Holmes JF, Mao A, Awasthi S, et al. [Validation of a prediction rule for the identification of children with intra-abdominal injuries after blunt torso trauma.](#) *Ann Emerg Med.* 2009 Oct;54(4):528-33.
26. Sokolove PE, Kuppermann N, Holmes JF. [Association between the "seat belt sign" and intra-abdominal injury in children with blunt torso trauma.](#) *Acad Emerg Med.* 2005 Sep;12(9):808-13.

## **Hemorrhage and fluid resuscitation**

1. Alberto EC, Mastrianni A, Sullivan TM, et al. [Factors affecting peripheral intravenous catheter placement during pediatric trauma resuscitation.](#) *J Surg Res.* 2023 Mar;283:241-248.
2. Quinn N, Ward G, Ong C, et al. [Mid-Arm Point in PAEDiatrics \(MAPPAED\): An effective procedural aid for safe pleural decompression in trauma.](#) *Emerg Med Australas.* 2022 Nov 23.
3. Callum JL, Yeh CH, Petrosioniak A, et al. [A regional massive hemorrhage protocol developed through a modified Delphi technique.](#) *CMAJ Open.* 2019 Sep 3;7(3):E546-E561.

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4. Noland DK, Apelt N, Greenwell C, et al. [Massive transfusion in pediatric trauma: An ATOMAC perspective](#). *J Pediatr Surg*. 2019 Feb;54(2):345-349.
5. Rosenfeld E, Lau P, Zhang W, et al. [Defining massive transfusion in civilian pediatric trauma](#). *J Pediatr Surg*. 2019 May;54(5):975-979.
6. Shroyer MC, Griffin RL, Mortellaro VE, Russell RT. [Massive transfusion in pediatric trauma: analysis of the National Trauma Databank](#). *J Surg Res*. 2017 Feb;208:166-172.
7. Cannon JW, Johnson MA, Caskey RC, et al. [High ratio plasma resuscitation does not improve survival in pediatric trauma patients](#). *J Trauma Acute Care Surg*. 2017 Aug;83(2):211-217.
8. Acker SN, Bredbeck B, Partrick DA, et al. [Shock index, pediatric age-adjusted \(SIPA\) is more accurate than age-adjusted hypotension for trauma team activation](#). *Surgery*. 2017 Mar;161(3):803-807.
9. Eckert MJ, Wertin TM, Tyner SD, et al. [Tranexamic acid administration to pediatric trauma patients in a combat setting: the pediatric trauma and tranexamic acid study \(PED-TRAX\)](#). *J Trauma Acute Care Surg*. 2014 Dec;77(6):852-8; discussion 858.
10. Hendrickson JE, Shaz BH, Pereira G, et al. [Coagulopathy is prevalent and associated with adverse outcomes in transfused pediatric trauma patients](#). *J Pediatr*. 2012 Feb;160(2):204-209.e3.
11. CRASH-2 trial collaborators, Shakur H, Roberts I, Bautista R, et al. [Effects of tranexamic acid on death, vascular occlusive events, and blood transfusion in trauma patients with significant haemorrhage \(CRASH-2\): a randomised, placebo-controlled trial](#). *Lancet*. 2010 Jul 3;376(9734):23-32.

## Other Resources

### Review articles

1. Evangelista ME, Gaffley M, Neff LP. [Massive transfusion protocols for pediatric patients: current perspectives](#). *J Blood Med*. 2020 May 21;11:163-172.
2. Mikrogianakis A, Grant V. [The kids are alright: Pediatric trauma pearls](#). *Emerg Med Clin North Am*. 2018 Feb;36(1):237-257.
3. Gilley M, Beno S. [Damage control resuscitation in pediatric trauma](#). *Curr Opin Pediatr*. 2018 Jun;30(3):338-343.
4. Fein DM, Fagan MJ. [Overall approach to trauma in the emergency department](#). *Pediatr Rev*. 2018 Oct;39(10):479-489.
5. Clebone A. [Pediatric trauma transfusion and cognitive aids](#). *Curr Opin Anaesthesiol*. 2018 Apr;31(2):201-206.
6. Wegner Araya A. [Reanimación con control de daños en el trauma grave pediátrico \[Damage control resuscitation in pediatric severe trauma\]](#). *Rev Chil Pediatr*. 2018 Feb;89(1):118-127.
7. Skelton T, Beno S. [Massive transfusion in pediatric trauma: We need to focus more on "how"](#). *J Trauma Acute Care Surg*. 2017 Jan;82(1):211-215.
8. Karam O, Tucci M. [Massive transfusion in children](#). *Transfus Med Rev*. 2016 Oct;30(4):213-6.
9. Yanchar NL, Warda LJ, Fuselli P. [Child and youth injury prevention: A public health approach](#). *Paediatr Child Health*. 2012 Nov;17(9):511-2.

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10. Kenefake ME, Swarm M, Walthall J. [Nuances in pediatric trauma](#). *Emerg Med Clin North Am*. 2013 Aug;31(3):627-52.

## **Podcasts**

1. Helman, A, Callum, J, Haas, B. et al. [Podcast Episode 152: The 7 Ts of Massive Hemorrhage Protocols](#). 2021.
2. Helman, A, Bosman, K, Hicks, C. et al. [Podcast Episode 119: Trauma the First and Last 15 Minutes \(Part 2\)](#). 2019.
3. Helman, A, Booth, K, Hicks, C, et al. [Podcast Episode 118: Trauma the First and Last 15 Minutes \(Part 1\)](#). 2018.
4. Beno S, Alnaji F. [Podcast Emergency Medicine Cases Podcast: Pediatric Trauma](#). 2017.

## **Training manuals**

1. American College of Surgeons. [ATLS \(Advanced Trauma Life Support\) Student Course Manual 10th Edition](#). 2018.