

Tourniquet usage in prehospital care and resuscitation of pediatric trauma patients—Pediatric Trauma Society position statement

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BACKGROUND:	Recent mass casualty events in the United States have highlighted the need for public preparedness to prevent death from uncontrolled hemorrhage. The Pediatric Trauma Society (PTS) reviewed the literature regarding pediatric tourniquet usage with the aim to provide recommendations about the utility of this adjunct for hemorrhage control in children.
METHODS:	Search terms “pediatric” and “tourniquet” were used to query the US National Library of Medicine National Institutes of Health for pertinent literature. Exclusion criteria include not involving children, not involving the use of an extremity tourniquet, primary outcomes not related to hemorrhage control, tourniquet use to prevent snake envenomation, single case reports, and only foreign language formats available. Bibliographies of remaining studies reviewed to identify additional pertinent research. Four physician members of the PTS Guidelines Committee reviewed identified studies.
RESULTS:	One hundred thirty-four studies were identified. One hundred twenty-three studies were excluded. Seven additional studies were identified through bibliography review. Eighteen pertinent studies were reviewed. Seven articles evaluated physiologic response to tourniquet use in operating room settings. Six articles were generated from combat experience in conflicts in Afghanistan and Iraq. Four articles discussed technical details of tourniquet usage. One article evaluated the use of tourniquets during the Boston Marathon bombing in 2015.
CONCLUSION:	Despite limited data of limited quality regarding their use, the PTS supports the usage of tourniquets in the prehospital setting and during the resuscitation of children suffering from exsanguinating hemorrhage from severe extremity trauma. Expedited, definitive care must be sought, and tourniquet pressure and time should be limited to the least amount possible. The Society supports the ACS “Stop the Bleed” campaign and encourages further investigation of tourniquet use in children. (<i>J Trauma Acute Care Surg</i> 2018;85: 665–667. Copyright © 2018 Wolters Kluwer Health, Inc. All rights reserved.)
LEVEL OF EVIDENCE:	Guidelines/algorithm study, level IIIa.
KEY WORDS:	Pediatric; tourniquet; extremity trauma; hemorrhage control; “Stop the Bleed”.

Recent mass casualty events in the United States have highlighted the need for public preparedness to enhance survivability following similar tragedies.^{1,2} In September 2015, the American College of Surgeons convened a commission to develop “common sense recommendations”³ for “strengthening the security and resilience of US citizens” after mass casualty events.⁴ The results of this effort are known as the “Hartford Consensus.”⁵ The “Stop the Bleed” campaign⁶ was developed from this group to disseminate knowledge to the general public, with the goal of eliminating preventable deaths from uncontrolled hemorrhage with widespread tourniquet use. Notably, this guideline and others⁷ make no mention of hemorrhage control in the

pediatric population. However, uncontrolled hemorrhage remains a significant cause of pediatric mortality following trauma.^{8,9}

AIM

The Pediatric Trauma Society (PTS) aims to reduce morbidity and mortality from uncontrolled hemorrhage following traumatic extremity injury. The goal of this study is to review the pertinent literature on tourniquet usage in the pediatric population and to provide a recommendation for their use in children.

MATERIALS AND METHODS

A systemic review of current available literature using US National Library of Medicine National Institutes of Health (PubMed) search with the terms “pediatric” and “tourniquet” yielded 134 studies. Exclusion criteria include not involving children, younger than 18 years (9), not involving the use of an extremity tourniquet (84), primary outcomes not related to hemorrhage control (22), tourniquet use to prevent snake envenomation (4), single case reports (2), and only foreign language formats available (2). The bibliographies of the remaining 11 studies were analyzed and an additional seven articles were identified for review. Ultimately, 18 studies were evaluated by a group of four physician members of the PTS Guidelines Committee. Two members of the group reviewed each article deemed significantly pertinent to formation of a position statement.

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REVIEW OF LITERATURE—SUMMARY

Eighteen studies were evaluated (see Appendix, Supplemental Digital Content 1, <http://links.lww.com/TA/B93>).

Summary of Physiologic Studies of Pediatric Tourniquet Usage

Seven articles^{10–16} evaluated physiologic response to tourniquet use in operating room settings. These demonstrated that tourniquets may increase metabolic acidosis, hypercarbia, and body temperature transiently though with unclear clinical significance. Patients with tourniquets undergoing regional anesthesia may have decreased endothelial dysfunction and oxidative stress compared with those under general anesthesia. The use of sympathetic blockade with epidural bupivacaine may decrease post-tourniquet syndrome, but is likely impractical in most trauma patients. Tourniquet usage greater than 75 minutes was shown to be associated with larger increases in lactate (>1.5 mmol/L), which correlate linearly with tourniquet time, and the resultant acidosis commonly resolves in greater than 10 minutes.¹⁶

Summary of Combat Experience With Pediatric Tourniquet Usage

Six articles^{17–22} were generated from combat experience in conflicts in Afghanistan and Iraq. These demonstrated that the usage of commercially available tourniquets was effective in soldiers and pediatric combat casualties. Trained military personnel demonstrated the utilization of tourniquets in nearly all patients with exsanguinating extremity injury. There was variability in the effectiveness of tourniquet application, with respect to appropriate occlusion of arterial flow and a suggestion of overuse in cases that did not likely need a tourniquet. Contrary to previous studies, complications from tourniquet use were rare. The use of tourniquets was effective in halting hemorrhage and decreasing mortality in children in combat settings. Notably, adult-sized tourniquets were used effectively in the pediatric population without increased complications and with survival rates similar to those reported in the adult literature¹⁹. Tourniquet usage increases survival by 92% over no tourniquet and an additional 13% when applied in a prehospital setting over application in the emergency department²⁰. Lastly, in a study of 766 pediatric trauma patients older than 8 years, tourniquets reduced resuscitation requirements with average transfusion reduced to 4.7 from 15 units and crystalloid reduced to 0.7 L from 3.0 L²¹. These data demonstrated a survival advantage in war-time utilization of tourniquets for military personnel and civilians with significant reductions in mortality if placed in the prehospital setting and before clinical signs of shock.

Summary of Adequacy of Hemostasis in Elective Operative Pediatric Tourniquet Usage

Four articles^{23–26} discussed technical details of tourniquet usage including specific devices used for vascular occlusion, tourniquet pressures, and duration and positioning of devices. Two observational studies^{24,26} found tourniquet cuff pressure inflated to occlusion pressure plus 50 mm Hg to provide adequate hemostasis based on surgeon survey. Their survey also found that tourniquet complications occur in 0.4% to 1.4% of all elective uses, with the majority of those injuries resulting in soft

tissue (31%) or nerve damage (21%). Overall, these studies generally demonstrated the effectiveness of several different products and outlined the techniques to minimize the deleterious effects of tourniquets.

Summary of Pediatric Tourniquet Experience During the Boston Marathon Bombing of 2015

One article²⁷ evaluated the use of tourniquets during the Boston Marathon bombing in 2015. It found that of the 66 patients with extremity injuries, tourniquets were only used in 27 patients, all in an improvised manner, and many not hemostatic. Despite this, all children who reached hospitals in the study group survived. The extension of combat lessons did not seem to be present in this civilian disaster.

DATA QUALITY

Level of evidence as described by Phillips et al.²⁸ from the Oxford Centre of Evidence-based Medicine was used to assign quality to the articles reviewed.

There is substantial heterogeneity among the articles reviewed. A plurality of studies was retrospective and observational in nature. The physiologic studies^{10–16} and those that described the adequacy of hemostasis in the elective pediatric orthopedic population^{23,24} were purely observational. Review of tourniquet usage in the pediatric combat population^{17–22}, as well as the summary of the tourniquet experience in the Boston marathon bombing²⁷, was retrospective in nature. Two randomized controlled trials^{14,25} were reviewed, and a literature review and survey were described by Tredwell et al.²⁶

Most studies included limited sample size and mixed populations of children and adults. Study populations included combat casualties, victims of terrorism, or patients undergoing orthopedic operating procedures. The level of evidence in 16 of 18 studies was either Level III or Level IV. Two studies were Level II (randomized controlled trial,^{14,25}), though not practical in trauma patients.^{28,29}

CONCLUSION

There remains limited data of limited quality regarding the use and utility of tourniquets in pediatric trauma patients. Despite this, recent experience in combat settings in Iraq and Afghanistan, as well as lessons learned from the Boston Marathon Bombing, has made the importance of a discussion about the use of this clinical adjunct timely. Tourniquet application has been demonstrated to increase survival and limit resuscitation in pediatric extremity trauma and observational studies demonstrate minor, quickly reversible physiologic changes from tourniquet usage. These devices have been shown to be effective and safe with low-risk for complications. Data regarding the harmful effects of tourniquet usage are limited to a small number of observational studies, and even then, they demonstrate low risk of soft tissue or nerve damage (0.4%–1.4%). Nevertheless, the overwhelming plurality of data demonstrates a distinct survival advantage with the use of tourniquets for extremity trauma in the prehospital setting. Commercially available tourniquets are appropriate for most children and not associated with significant complications. The use of tourniquets in military settings

of severely injured patients fosters caution in civilian settings where the extent of extremity trauma is generally less severe than combat.

RECOMMENDATIONS

The PTS supports the usage of tourniquets in the pre-hospital setting and during the resuscitation of children suffering from exsanguinating hemorrhage from severe extremity trauma. Direct pressure at or immediately proximal to the site of injury should always be the initial technique for hemorrhage control. If this fails to control exsanguinating hemorrhage or is too resource intensive, a tourniquet should be applied proximal to the site of injury and inflated or tightened to a pressure that controls bleeding. Tourniquets should be frequently reevaluated after placement for appropriate positioning and adequate control of bleeding. Duration of tourniquet use may impact limb salvage. The risk of exsanguinating hemorrhage outweighs tourniquet-related morbidity. Expedited, definitive care must be sought, and tourniquet pressure and time should be limited to the least amount possible. The Society supports the American College of Surgeons “Stop the Bleed” campaign and encourages further investigation of tourniquet use in children.

GRADE OF RECOMMENDATION

The grade of these recommendations based on quality of evidence would be C/D.^{10,11} This is a result of using a majority of studies that were observational, retrospective, and not controlled. The nature of injuries necessitating tourniquet use makes randomization difficult. Despite the quality of this evidence, the PTS strongly supports these recommendations.

AUTHORSHIP

M.J., M.A., M.C., A.C. participated in the study design. A.C. participated in the data acquisition. M.J., M.A., M.C., A.C. participated in the data analysis. M.J., M.A., M.C., A.C. participated in the data interpretation. M.J., A.C. participated in the drafting of the article. M.J., M.A., M.C., A.C. participated in the revision of the article.

DISCLOSURE

The authors declare no conflicts of interest.

REFERENCES

- Jacobs LM, Burns KJ. The Hartford Consensus: Survey of the Public and Healthcare Professionals on Active Shooter Events in Hospitals. *J Am Coll Surg*. 2017;225(3):435–442.
- Knudson MM. When peace breaks out: The 42nd American Association for the Surgery of Trauma Fitts Oration. *J Trauma Acute Care Surg*. 2017;82(1):10–17.
- Biden JR Jr. Letter from the Vice-President. Equipping citizens with the skills to respond to mass casualty incidents. *Bull Am Coll Surg*. 2015;100(Suppl 1):9.
- American College of Surgeons, Compendium of Strategies to Enhance Victims' Survivability from Mass Casualty Events. *Bull Am Coll Surg*. 2015. 100(Suppl 1).
- Jacobs LM, Wade D, McSwain NE, Butler FK, Fabbri W, Eastman A, Conn A, Burns KJ. Hartford Consensus: a call to action for THREAT, a medical disaster preparedness concept. *J Am Coll Surg*. 2014;218(3):467–475.
- Holcomb J, Butler F, Rhee P. Hemorrhage control devices: Tourniquets and hemostatic dressings. *Bull Am Coll Surg*. 2015;100(Suppl 1):66.
- Bulger EM, Snyder D, Schoelles K, Gotschall C, Dawson D, Lang E, Sanddal ND, Butler FK, Fallat M, Taillac P, et al. An Evidence-based Prehospital Guideline for External Hemorrhage Control: American College of Surgeons Committee on Trauma. *Prehosp Emerg Care*. 2014;18(2):163–173.
- Diamond IR, Parkin PC, Wales PW, Bohn D, Kreller MA, Dykes EH, McLellan BA, Wesson DE. Preventable pediatric trauma deaths in Ontario: a comparative population-based study. *J Trauma*. 2009;66(4):1189–1194 discussion 1194–5.
- Sauaia A, Moore FA, Moore EE, Moser KS, Brennan R, Read RA, Pons PT. Epidemiology of trauma deaths: a reassessment. *J Trauma*. 1995;38(2):185–193.
- Bloch EC. Hyperthermia resulting from tourniquet application in children. *Ann R Coll Surg Engl*. 1986;68(4):193.
- Bloch EC, Ginsberg B, Binner RA Jr, Sessler DI. Limb tourniquets and central temperature in anesthetized children. *Anesth Analg*. 1992;74(4):486–489.
- Brustowicz RM, Moncorce C, Koka BV. Metabolic responses to tourniquet release in children. *Anesthesiology*. 1987;67(5):792–794.
- Budic IV, Pavlovic DU, Kocic GO, Cvetkovic TA, Simic DU, Basic JE, Zivanovic DR. Biomarkers of oxidative stress and endothelial dysfunction after tourniquet release in children. *Physiol res*. 2011;60:S137.
- Goodarzi M, Shier NH, Grogan DP. Does sympathetic blockade prevent the physiologic changes associated with tourniquet use in children? *J Pediatr Orthop*. 1997;17(3):289–292.
- Goodarzi M, Shier NH, Ogden JA. Physiologic changes during tourniquet use in children. *J Pediatr Orthop*. 1992;12(4):510–513.
- Lynn AM, Fischer T, Brandford HG, Pendergrass TW. Systemic responses to tourniquet release in children. *Anesth Analg*. 1986;65(8):865–872.
- Dua A, Via KC, Kreishman P, Kragh JF, Spinella PC, Patel B, Gillespie DL, Mahoney P, Fox CJ. Early management of pediatric vascular injuries through humanitarian surgical care during US military operations. *J Vasc Surg*. 2013;58(3):695–700.
- King DR, van der Wilden G, Kragh JF Jr, Blackburne LH. Forward assessment of 79 prehospital battlefield tourniquets used in the current war. *J Spec Oper Med*. 2012;12(4):33–38.
- Kragh JF, Cooper A, Aden JK, Dubick MA, Baer DG, Wade CE, Blackburne LH. Survey of trauma registry data on tourniquet use in pediatric war casualties. *Pediatr Emerg Care*. 2012;28(12):1361–1365.
- Kragh JF Jr, Walters TJ, Baer DG, Fox CJ, Wade CE, Salinas J, Holcomb JB. Survival with emergency tourniquet use to stop bleeding in major limb trauma. *Ann Surg*. 2009;249(1):1–7.
- Sokol KK, Black GE, Azarow KS, Long W, Martin MJ, Eckert MJ. Prehospital interventions in severely injured pediatric patients: Rethinking the ABCs. *J Trauma Acute Care Surg*. 2015;79(6):983–990.
- Villamaria CY, Morrison JJ, Fitzpatrick CM, Cannon JW, Rasmussen TE. Wartime vascular injuries in the pediatric population of Iraq and Afghanistan: 2002–2011. *J Pediatr Surg*. 2014;49(3):428–432.
- Eidelman M, Katzman A, Bialik V. A novel elastic exsanguination tourniquet as an alternative to the pneumatic cuff in pediatric orthopedic limb surgery. *J Pediatr Orthop B*. 2006;15(5):379–384.
- Lieberman JR, Staheli LT, Dales MC. Tourniquet pressures on pediatric patients: a clinical study. *Orthopedics*. 1997;20(12):1143–1147.
- Reilly CW, McEwen JA, Leveille L, Perdios A, Mulpuri K. Minimizing tourniquet pressure in pediatric anterior cruciate ligament reconstructive surgery: a blinded, prospective randomized controlled trial. *J Pediatr Orthop*. 2009;29(3):275–280.
- Tredwell SJ, Wilkink M, Inkpen K, McEwen JA. Pediatric tourniquets: analysis of cuff and limb interface, current practice, and guidelines for use. *J Pediatr Orthop*. 2001;21(5):671–676.
- King DR, Larentzakis A, Ramly EP. Tourniquet use at the Boston Marathon bombing: Lost in translation. *J Trauma Acute Care Surg*. 2015;78(3):594–599.
- Phillips B, Ball C, Badenoch D, Straus S, Haynes B, Dawes M. Oxford centre for evidence-based medicine levels of evidence (May 2001). *BJU Int*. 2011;107(5):870.
- Guyatt GH, Oxman AD, Vist GE, Kunz R, Falck-Ytter Y, Alonso-Coello P, Schünemann HJ. Rating quality of evidence and strength of recommendations: GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. *BMJ*. 2008;336(7650):924.