Batın Travmalı Hastada Hemodinamik Stabilizasyon

Prof. Dr. Suat Zengin
Twt(@prof_suat)
İnst(@prof.dr.suat_zengin)

Ölüm oranları daha yüksek.

- Vücut kütleleri küçük ve birim alana daha fazla enerji iletilir.
- Karın duvarının; bağ, yağ dokusu ve kas tabakası ince, kostalar daha esnek.
- Batın içi organlar daha büyük ve birbirine daha yakın.

Koagülopati

- Kanama kaynaklı faktör kayıpları,
- Endotel hasarı kaynaklı tüketim kayıpları,
- Kristaloid ürün kullanımı kaynaklı hemodilüsyon.

Şokun Erken Tanısı (ATLS-2025)

- Kan hacminin %30-40'ı kaybedilene kadar **kan basıncı** normal sınırda olabilir.
- Taşikardi ve zayıf periferik nabız; **şokun en erken bulgusudur**.
- Ağrı, korku veya psikolojik strese !!!!
- Kapiller geri dolum süresinin >2 saniye olması,
- Soğuk ve soluk ekstremiteler.
- Tırnak yatağı renginin ve dudak renginin soluklaşması,
- Ajitasyon, letarji veya çevreye yanıtsızlık.
- İdrar Çıkışı <1-2 mL/kg/saat dikkatle izlenmelidir ancak genellikle daha geç dönemde ortaya çıkarlar.

Taşikardi ve zayıf periferik nabız çocuklarda hipovoleminin erken bulgularıdır ve sıvı resüsitasyonunun erken başlatılmasının en iyi göstergeleridir.

Kan Kaybının Fizyolojik Etkileri (ATLS-2025)

Sistem	Hafif Kan Kaybı (< %30)	Orta Derecede Kan Kaybı (%30–%45)	Şiddetli Kan Kaybı (> %45)
Kardiyovasküler	Artmış kalp hızı; zayıf, periferik nabızlar; normal sistolik kan basıncı (80 + 2 × yaş); normal nabız basıncı	Belirgin şekilde artmış kalp hızı; zayıf, ipliksi merkezi nabızlar yok; düşük normal sistolik kan basıncı (65+ 2 × yaş); daralmış nabız basıncı	Taşikardiyi takiben bradikardi; çok zayıf nabızlar; hipotansiyon (<65 + 2 × yaş) daralmış nabız basıncı (veya saptanamayan diyastolik kan basıncı)
Merkezi Sinir Sistemi	Endişeli; huzursuz; kafası karışık	Letarjik; ağrıya karşı donuk tepki	Koma
Deri	Soğuk, benekli; uzamış kapiller geri dolum	Siyanotik; belirgin şekilde uzamış kapiller geri dolum	Soluk ve soğuk
İdrar Çıkışı	Düşük normal*	Minimal	Yok

•*Düşük normal 2 ml/kg/saat (bebek), 1,5 ml/kg/saat (küçük çocuk), 1 ml/kg/saat (büyük çocuk) ve 0,5 ml/hg/saattir (ergen)*

•Sistolik KB üst sınır=80 mm Hg+2XYaş . Sistolik KB alt sınırı=65 mm Hg+2XYaş . Diyastolik Basınç=2/3X Sistolik KB

MOTTLiNG SKORU

ŞOKTA SESSİZ AMA ÖLÜMCÜL BİR BULGUDUR

Nedir?

- **Dokuya yeterli kan** gitmediğinin göstergesidir
- **Mikrosirkülasyon** bozukluğunu gösterir

Nerede Görülür?

- Septik şok
- Hipovolemik şok
- Kardiyojenik şok
- İleri perfüzyon bozukluğu

Skor Nasıl Değerlendirilir?

- 0 Mottling yok
- 1 Diz üzerinde küçük alan
- 2 Diz kapağı üstüne kadar
- 3 Uyluk ortasına kadar
- 4 Kasik kıvrımına kadar
- 5 Kasık ötesine yayılmış



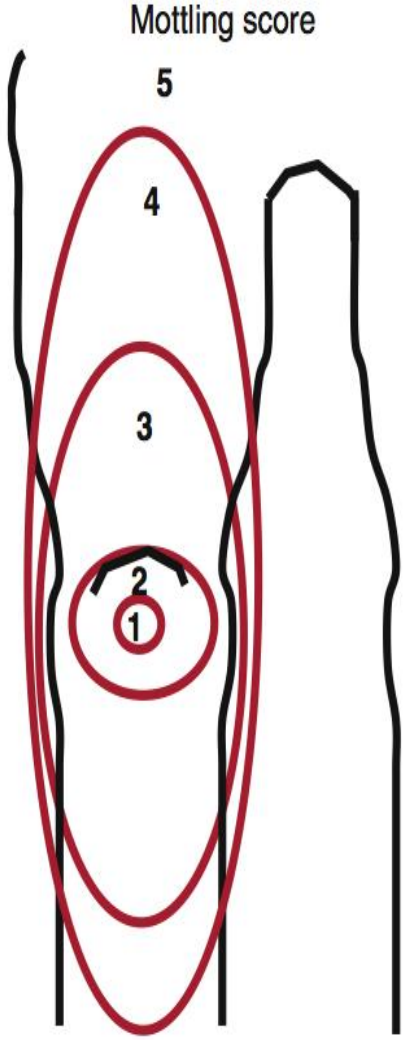
Klinik Önemi

Skor arttıkça:

- **Doku hipoksisi** artar
- **Organ** yetmezliği riski artar
- **Mortalite** artar

Akılda Kalıcı Bilgi

→ Mottling = Kötü perfüzyon = Ağır şok







SCORE 2 SCORE 4

Bu prospektif çalışmada, **birden fazla kristaloid bolusu**; artan transfüzyon gereksinimi ve uzamış mekanik ventilasyon ile hastanede yatış süreleri dahil olmak üzere daha kötü klinik sonuçlarla ilişkilendirilmiştir. Bu veriler, yaralanmış çocukların resüsitasyonunda kristaloid kullanımını sınırlayan ve erken transfüzyonu önceleyen bir yaklaşımı desteklemektedir.

2020 EAST Podium Paper

Timing and volume of crystalloid and blood products in pediatric trauma: An Eastern Association for the Surgery of Trauma multicenter prospective observational study

Stephanie F. Polites, MD, MPH, Suzanne Moody, MPA, Regan F. Williams, MD, MSE, Mark L. Kayton, MD, Emily C. Alberto, MD, Randall S. Burd, MD, PhD, Thomas J. Schroeppel, MD, MS, Joanne E. Baerg, MD, Amanda Munoz, MD, William B. Rothstein, MD, Laura A. Boomer, MD, Eric M. Campion, MD, Caitlin Robinson, MPH, CRA, Rachel M. Nygaard, PhD, Chad J. Richardson, MD, Denise I. Garcia, MD, MEd, Christian J. Streck, MD, Michaela Gaffley, MD, John K. Petty, MD, Cynthia Greenwell, BSN, RN, Samir Pandya, MD, Alicia M. Waters, MD, Robert T. Russell, MD, MPH, Brian K. Yorkgitis, DO, Jennifer Mull, RN, Jeffrey Pence, MD, Matthew T. Santore, MD, Taleen MacArthur, MD, Denise B. Klinkner, MD, MEd, Shawn D. Safford, MD, MAS, Tanya Trevilian, MSN, RN, CCRN-K, CPN, Adam M. Vogel, MD, Megan Cunningham, MD, Christa Black, MPH, Jessica Rea, MD, Ryan G. Spurrier, MD, Aaron R. Jensen, MD, MEd, Bethany J. Farr, MD, David P. Mooney, MD, MPH, Bavana Ketha, MD, Melvin S. Dassinger III, MD, Anna Goldenberg-Sandau, DO, Janika San Roman, MPH, Todd M. Jenkins, PhD, MPH, *and* **Richard A. Falcone, Jr., MD, MPH**, *Cincinnati, Ohio*

BACKGROUND: The purpose of this study was to determine the relationship between timing and volume of crystalloid before blood products and mortality, hypothesizing that earlier transfusion and decreased crystalloid before transfusion would be associated with improved outcomes.

METHODS: A multi-institutional prospective observational study of pediatric trauma patients younger than 18 years, transported from the scene of injury with elevated age-adjusted shock index on arrival, was performed from April 2018 to September 2019. Volume and timing of prehospital, emergency department, and initial admission resuscitation were assessed including calculation of 20 ± 10 mL/kg crystalloid boluses overall and before transfusion. Multivariable Cox proportional hazards and logistic regression models identified factors associated with mortality and extended intensive care, ventilator, and hospital days.

RESULTS: In 712 children at 24 trauma centers, mean age was 7.6 years, median (interquartile range) Injury Severity Score was 9 (2–20), and in-hospital mortality was 5.3% (n = 38). There were 311 patients(43.7%) who received at least one crystalloid bolus and 149 (20.9%) who received blood including 65 (9.6%) with massive transfusion activation. Half (53.3%) of patients who received greater than one crystalloid bolus required transfusion. Patients who received blood first (n = 41) had shorter median time to transfusion (19.8 vs. 78.0 minutes, $p = 0.005$) and less total fluid volume (50.4 vs. 86.6 mL/kg, $p = 0.033$) than those who received crystalloid first despite similar Injury Severity Score (median, 22 vs. 27, $p = 0.40$). On multivariable analysis, there was no association with mortality ($p = 0.51$); however, each crystalloid bolus after the first was incrementally associated with increased odds of extended ventilator, intensive care unit, and hospital days (all $p < 0.05$). Longer time to transfusion was associated with extended ventilator duration (odds ratio, 1.11; $p = 0.04$).

CONCLUSION: Resuscitation with greater than one crystalloid bolus was associated with increased need for transfusion and worse outcomes including extended duration of mechanical ventilation and hospitalization in this prospective study. These data support a crystalloid-sparing, early transfusion approach for resuscitation of injured children. (*J Trauma Acute Care Surg.* 2020;89: 36–42. Copyright © 2020 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Therapeutic, level IV.

KEY WORDS: Pediatric trauma; resuscitation; crystalloid; transfusion; hemorrhagic shock.

Pediatrik travma hastalarında, component tedavisine ek olarak tam kan kullanımı; azalmış transfüzyon gereksinimi ve daha az ventilasyon günü ile ilişkilendirilmiştir.

Whole blood hemostatic resuscitation in pediatric trauma: A nationwide propensity-matched analysis

Tanya Anand, MD, Omar Obaid, MD, Adam Nelson, MD, Mohamad Chehab, MD, Michael Ditillo, DO, Ahmad Hammad, MD, Molly Douglas, MD, Letitia Bible, MD, *and* **Bellal Joseph, MD, FACS**, *Tucson, Arizona*

BACKGROUND: Whole blood (WB) has shown promise in pediatric trauma resuscitation following its prominent role in the resuscitation of adult trauma patients. Although WB in children has been shown to be feasible, its effectiveness has yet to be explored. The aim of this study was to examine the outcomes of WB transfusion as an adjunct to component therapy (CT) compared with CT only as early resuscitation for pediatric trauma patients.

METHODS: Children aged 1 to 17 years, who were transfused within 4 hours of presentation, were identified in the Trauma Quality Improvement Program 2017 database. Patients were stratified into those receiving WB-CT versus CT alone. Propensity score matching in a 1:2 ratio was performed based on patient demographics, injury characteristics, hemorrhage control interventions, and trauma center level. The primary outcome measure was patient transfusion requirement. Secondary outcome measures were mortality, hospital length of stay, ventilation days, and major complications.

RESULTS: A total of 135 children receiving WB-CT were matched to 270 patients receiving CT only. Mean (SD) age was 12 (5) years, 66% were male, and the median Injury Severity Score was 32 (range, 20–43). A total of 51% of patients were in shock, 34% had penetrating injuries, and 41% required surgical intervention for hemorrhage control. Total blood products transfused were significantly decreased in children receiving WB, both at 4 hours (35 [22–73] vs. 48 [33–95] mL/kg; $p = 0.013$) and 24 hours (39 [24–97] vs. 53 [36–119] mL/kg; $p < 0.001$). Mortality rate at 24 hours (19.3% vs. 21.9%; $p = 0.546$) and in-hospital mortality (31.1% vs. 34.4%; $p = 0.502$) were not different. Similarly, no difference in hospital length of stay and rates of major complications was found. Patients in the WB group required significantly less ventilation days (2 [2–6] vs. 3 [2–8] days; $p = 0.021$).

CONCLUSION: Using WB as an adjunct to CT was associated with decreased transfusion requirements and ventilation days in pediatric trauma patients. (*J Trauma Acute Care Surg.* 2021;91: 573–578. Copyright © 2021 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Therapeutic, level III.

KEY WORDS: Whole blood; component therapy; pediatrics; trauma; hemorrhage.

Acil servisteki ilk saatte 20 cc/kg'lık birden fazla intravenöz sıvı bolusu uygulanması, mortalite ile ilişkilendirilmiştir. (2021)

- Daha önce kristaloid resüsitasyonu tercih ediliyordu, ancak bu stratejinin mortaliteyi artırdığı ve sonuçları kötüleştirdiği bulundu ve hasar kontrolü resüsitasyonu kavramıyla değiştirildi (DCR).

Available online at www.sciencedirect.com
ScienceDirect
journal homepage: www.JournalofSurgicalResearch.com
ELSEVIER
JSR Journal of Surgical Research

Higher Crystalloid Volume During Initial Pediatric Trauma Resuscitation is Associated With Mortality

Nina Mbadiwe, MD,[a,1] *Nathan Georgette, MD,*[a,*] *Mark B. Slidell, MD, MPH,*[b] *and Alisa McQueen, MD*[a]

[a] *Department of Pediatrics, Comer Children's Hospital of the University of Chicago, Chicago, Illinois*
[b] *Department of Pediatric Surgery, Comer Children's Hospital of the University of Chicago, Chicago, Illinois*

ARTICLE INFO

Article history:
Received 11 September 2020
Received in revised form
20 December 2020
Accepted 26 December 2020
Available online 6 February 2021

Keywords:
Pediatric trauma
IVF
Crystalloid
Resuscitation
Cohort study

ABSTRACT

Background: Historically, aggressive fluid resuscitation has been a cornerstone of management of hemorrhagic shock in pediatrics. Adult data suggest this strategy may be harmful. We sought to determine whether aggressive fluid resuscitation within the first hour of presentation to the emergency department in pediatric patients with trauma is associated with worse clinical outcomes.

Materials and methods: We performed a retrospective cohort study from 2012 to 2017 at a single pediatric level 1 trauma center. We defined three patient cohorts: ≤ 20 cc/kg (reference), 20-40 (20.01 to 39.99) cc/kg, and ≥40 cc/kg of intravenous fluid (IVF) given in the first in-hospital hour. Covariates included age, injury severity score, shock index (adjusted for age), and mechanism of injury and were adjusted for with multivariable regression. The primary outcome was in-hospital mortality.

Results: A total of 1479 consecutive injured children were eligible for inclusion. One hundred ninety-four patients were excluded for missing IVF data, aged ≥16 y, having primary burns, or arriving pulseless. A total of 1285 patients met inclusion criteria (mean age 8.1 ± 5.5 y, male 64.5%). Higher rates of IVF administration were associated with mortality for both the 20-40 cc/kg (adjusted odds ratio (aOR) 2.96; 95% confidence interval (CI) 1.02-8.55; $P = 0.045$) and ≥40 cc/kg groups (aOR 6.26; 95% CI 1.79-21.83; $P = 0.004$). The ≥40 cc/kg group was associated with increased pediatric intensive care unit length of stay (aOR 2.20; 95% CI: 1.05-4.61; $P = 0.036$) and increased need for mechanical ventilation (aOR 3.79; 95% CI 1.62-8.87; $P = 0.002$).

Conclusions: Greater than one 20 cc/kg IVF bolus in the first emergency department hour was associated with mortality with a dose-response relationship, even after adjusting for injury severity and initial hemodynamics. These results encourage further investigation into initial resuscitation strategies for injured children.

© 2021 Elsevier Inc. All rights reserved.

Verilerimiz, taze tam kanın, ciddi kafa yaralanması olmayan çocuklarda daha iyi hayatta kalma ile ilişkili olabileceğini göstermektedir. (2021)

SUPPLEMENT ARTICLE

TRANSFUSION

An analysis of outcomes for pediatric trauma warm fresh whole blood recipients in Iraq and Afghanistan

Ryann S. Lauby[1] | **Camaren M. Cuenca**[1] | **Matthew A. Borgman**[2,3] | **Andrew D. Fisher**[4,5] | **Vikhyat S. Bebarta**[6] | **Earnest E. Moore**[6] | **Philip C. Spinella**[7] | **James Bynum**[1] | **Steven G. Schauer**[1,2,3]

[1]US Army Institute of Surgical Research, JBSA Fort Sam Houston, San Antonio, Texas, USA

[2]Brooke Army Medical Center, JBSA Fort Sam Houston, San Antonio, Texas, USA

[3]Uniformed Services University of the Health Sciences, Bethesda, Maryland, USA

[4]Department of Surgery, University of New Mexico School of Medicine, Albuquerque, New Mexico, USA

[5]Medical Command, Texas Army National Guard, Austin, Texas, USA

[6]Center for COMBAT Research, Department of Emergency Medicine, University of Colorado Anschutz Medical Campus, Aurora, Colorado, USA

[7]Department of Pediatrics, Division of Critical Care, Washington University in St. Louis, St. Louis, Missouri, USA

Correspondence
Steven G. Schauer, Steven Schauer 3698 Chambers Pass, JBSA Fort Sam Houston, TX 78234-7767, USA.
Email: steven.g.schauer.mil@mail.mil

Abstract

Background: Whole blood therapy—which contains the ideal balance of components, and particularly fresh whole blood—has been shown to be beneficial in adult trauma. It remains unclear whether there is potential benefit in the pediatric population.

Study Design and Methods: This is a secondary analysis of previously published data analyzing pediatric casualties undergoing massive transfusion in the Department of Defense Trauma Registry. Pediatric patients with traumatic injury who were transfused at least one blood product were included in the analysis. We compared children who received component therapy exclusively to those who received any amount of warm fresh whole blood.

Results: Of the 3439 pediatric casualties within our dataset, 1244 were transfused at least one blood product within the first 24 h. There were 848 patients without severe head injury. Within this cohort, 23 children received warm fresh whole blood overall, 20 of whom did not have severe head injury. In an adjusted analysis, the odds ratio (95% confidence interval [CI]) for survival for warm fresh whole blood recipients was 2.86 (0.40–20.45). After removing children with severe brain injury, there was an independent association with improved survival for warm fresh whole blood recipients with an odds ratio (95% CI) of 58.63 (2.70–1272.67).

Discussion: Our data suggest that warm fresh whole blood may be associated with improved survival in children without severe head injury. Larger prospective studies are needed to assess the efficacy and safety of whole blood in children with severe traumatic bleeding.

Pediatrik travma hastaları için olan yaklaşımlar, uzman görüşüne veya yetişkin hastalar üzerinde yapılan çalışmalara dayanmaktadır. Pediatrik hastalarda dengeli bir transfüzyon yaklaşımı önermek mantıklıdır (2022).

Geçmişteki kanıtlar, önceki on yıllarda pediatrik alanda resüsitasyon için kristaloidlerin kullanımını destekliyordu; ancak son zamanlarda...

Çalışmalar, travma hastalarının canlandırılmasında kristaloid solüsyonlardan kaçınılmasını ve tam kan kullanılmasını teşvik etmektedir.

Journal of Pediatric Surgery 57 (2022) 986–993

Contents lists available at ScienceDirect

Journal of Pediatric Surgery

journal homepage: www.elsevier.com/locate/jpedsurg.org

Balanced hemostatic resuscitation for bleeding pediatric trauma patients: A nationwide quantitative analysis of outcomes

Malak Akl, Tanya Anand, Raul Reina, Khaled El-Qawaqzeh, Michael Ditillo, Hamidreza Hosseinpour, Adam Nelson, Omar Obaid, Randall Friese, Bellal Joseph*

Division of Trauma, Critical Care, Emergency Surgery, and Burns, Department of Surgery, College of Medicine, University of Arizona, 1501 N. Campbell Ave, Room 5411, P.O. Box 245063, Tucson, AZ 85724, USA

ARTICLE INFO

Article history:
Received 19 January 2022
Revised 4 June 2022
Accepted 4 July 2022

Keywords:
Pediatrics
Trauma
Hemorrhage

ABSTRACT

Background: The administration of balanced component therapy has been associated with improvements in outcomes in adult trauma. There is little to no specific data to guide transfusion ratios in children. The aim of our study is to compare outcomes among different transfusion strategies in pediatric trauma patients.

Methods: We conducted a (2014–2016) retrospective analysis of the Trauma Quality Improvement Program. We selected all pediatric (age < 18) trauma patients who received at least one unit of packed red blood cells (PRBC) and fresh frozen plasma (FFP) within 4 h of admission. Patients were stratified based on their FFP:PRBC transfusion ratio in the first 4 h into: 1:1, 1:2, 1:3, and 1:3+. Primary outcomes were 24-mortality, in-hospital mortality. Secondary outcomes were complications and 24 h PRBC transfusion

bidities (diabetes mellitus, prematurity, congenital disorders), and ACS Pediatric Trauma Center Verification level (level I, level II, and others). In our analysis, alpha was set at 5% and a *p*-value of less than 0.05 ($p < 0.05$) was considered statistically significant. We used the Statistical Package for Social Services (SPSS, version 28; SPSS Inc., Armonk, NY) to perform all of our statistical analyses. We adhered to the Strengthening of the Reporting of Observational Studies in Epidemiology (STROBE) guidelines (please see supplemental digital content for the full STROBE guidelines checklist).

3. Results

We identified 123,835 pediatric trauma patients, of which 1233 patients received at least one unit of PRBC and at least one unit of FFP within 4 h of presentation. A total of 44 patients (1.8%) had missing data, and were excluded from the analysis. Fig. 1 illustrates the flow diagram of patients included in the final analysis. Among these patients, 637 (51.6%) received a FFP:PRBC transfusion ratio of 1:1, 365 (29.6%) received a FFP:PRBC transfusion ratio of 1:2, 116 (9.4%) received a FFP:PRBC transfusion ratio of 1:3, and 115 (9.3%) received a FFP:PRBC transfusion ratio of less than 1:3. The mean age of our study cohort was 11 ± 6y, 70% of patients were male, the median ISS was 27 [20–38], and 62% sustained penetrating injuries. Baseline characteristics between the four groups were similar except for volumes of PRBC and FFP transfused within the first 4 h ($p < 0.01$). Overall, 65% of patients met the definition of pediatric massive transfusion, and patients in the lower FFP:PRBC ratio groups were more likely to meet massive transfusion definition than those in the higher FFP:PRBC transfusion ratio groups ($p < 0.01$). The baseline characteristics of the study cohort are described in Table 1.

Overall in our study cohort, the 24 h mortality was 17%, and the in-hospital mortality was 35%. Patients required a median of 4 [2–9] units of PRBC within 24 h of admission. The overall major complication rate was 22%, and the most common complication was infectious (10%), followed by cardiac arrest (10%). Patients in the higher FFP:PRBC transfusion ratio groups had lower vs. 1:3+, 44%; $p < 0.01$), and 24 h PRBC transfusion requirements (1:1, 3 [2–7] vs. 1:2, 5 [2–10] vs. 1:3, 6 [3–8] vs. 1:3+, 6 [4–10] units; $p < 0.01$) as compared to patients in the lower FFP:PRBC transfusion ratio groups. There were no differences between the four groups in terms of the rates of overall major complications ($p = 0.96$), unplanned return to the OR ($p = 0.91$), unplanned intubation ($p = 0.59$), unplanned ICU admission ($p = 0.20$), and hospital LOS ($p = 0.33$) and ICU LOS ($p = 0.66$). The outcome measures of the four study groups are described in Table 2.

On multivariate regression analysis, progressive increases in the adjusted odds ratios for both 24 h and in-hospital mortality were observed as the FFP:PRBC transfusion ratio decreased. There was no independent association observed between the FFP:PRBC transfusion ratio and in-hospital complications. The adjusted odds ratios for the study outcomes are provided in Table 3. Fig. 2 illustrates the progressive decrease in the adjusted odds ratio for mortality as FFP:PRBC transfusion ratio increases. Fig. 3 illustrates the Kaplan-Meier survival analysis curves for the different FFP:PRBC transfusion ratio groups. A distinct time of separation of the curves was visually noted within the 24 h timepoint, and higher FFP:PRBC transfusion ratio was consistently associated with higher survival across the time period of observation.

4. Discussion

The results of our study indicate that resuscitation of pediatric trauma patients with higher FFP:PRBC transfusion ratios, approximating the constituency of whole blood, is associated with lower 24 h pRBC transfusion requirements and increased 24 h and in-hospital survival. Our results also showed that there were no differences in-hospital complications between the four different transfusion ratio groups.

Past evidence supported the use of crystalloids for resuscitation in the pediatric arena in previous decades; however, recent studies encourage the avoidance of crystalloids and the employment of whole blood for trauma patients resuscitation, including the pediatric population. Mbadiwe et al. concluded that the use of

1.2: Hemorajik şoka giren çocuklarda, resüsitasyon için mevcutsa, kan bileşenleri (eritrosit, plazma ve trombositler) yerine O grubu tam kan kullanımı düşünülebilir.

Author Manuscript
Author Manuscript
Author Manuscript

HHS Public Access
Author manuscript
J Trauma Acute Care Surg. Author manuscript; available in PMC 2024 January 01.

Published in final edited form as:
J Trauma Acute Care Surg. 2023 January 01; 94(1): S2–S10. doi:10.1097/TA.0000000000003805.

Pediatric Traumatic Hemorrhagic Shock Consensus Conferenc Recommendations

Robert T. Russell, MD, MPH[1], Joseph R. Esparaz, MD, MPH[1], Michael A. Beckwith, MD[2], Peter J. Abraham, MD[3], Melania M. Bembea, MD, PhD, MPH, PhD[4], Matthew A. Borgman, MD[5], Randall S. Burd, MD, PhD[6], Barbara A. Gaines, MD[7], Mubeen Jafri, MD[8], Cassandra D. Josephson, MD[9], Christine Leeper, MD[10], Julie C. Leonard, MD, MPH[11], Jennifer A. Muszynski, MD, MPH[12], Kathleen K. Nicol, MD[13], Daniel K. Nishijima, MD, MAS[14], Paul A Stricker, MD[15], Adam M. Vogel, MD[16], Trisha E. Wong, MD, MS[17], Philip C. Spinella, MD[18]

[1]Department of Surgery, Division of Pediatric Surgery, University of Alabama at Birmingham, Children's of Alabama, Birmingham, AL

[2]Department of Surgery, Division of Pediatric Surgery, University of Michigan, Ann Arbor, MIS

[3]Department of Surgery, University of Alabama at Birmingham, Birmingham, AL

[4]Division of Anesthesiology and Critical Care Medicine, Johns Hopkins University School of Medicine, Baltimore, MD

[5]Department of Pediatrics, Brooke Army Medical Center, Uniformed Services University

[6]Division of Trauma and Burn Surgery, Children's National Hospital, Washington, DC

[7]Department of Surgery, University of Pittsburgh School of Medicine, UPMC Children's Hospita Pittsburgh, PA.

[8]Division of Pediatric Surgery, Doernbecher Children's Hospital, Oregon Health and Science University, Portland, OR

[9]Departments of Pathology and Laboratory Medicine and Pediatrics, Emory University School Medicine, Atlanta, GA

volumes was not associated with improved survival (OR 0.61; [0.28–1.29]). The authors concluded that the high crystalloid volume negated the potential survival benefit of high plasma:RBC ratios in children with severe traumatic bleeding.

A secondary analysis of the PAMPer trial showed similar findings. This study of injured adults compared four groups of patients based on prehospital resuscitation with PRBC and plasma, plasma only, PRBC only, and crystalloid only. For patients with severe traumatic bleeding, they found that the exclusive use of crystalloids worsened survival compared to the partial use of blood products in the prehospital resuscitation phase.[17] A second RCT in adults with severe traumatic injury showed the use of crystalloids in the prehospital phase of resuscitation decreased the risk of survival compared to not using any crystalloids or blood products.[18]

Pediatric and adult data supports the association of crystalloids with worse outcomes and the increased and early use of blood products (whole blood or balanced approach) with improved survival. These data support our recommendation suggesting the prioritization of blood products over crystalloids for the resuscitation of traumatic hemorrhagic shock in children.

1.2: In traumatically injured children in hemorrhagic shock, the use of low titer (≤ 200 Ig G) group O whole blood might be considered if available over individual blood components (RBC, plasma, and platelets) for resuscitation. *Clinical Recommendation, conditional recommendation, very low certainty of evidence, 94% agreement (n=16), Median 8.5, IQR: 7.75–9.*

1.3: Travmatik yaralanma sonucu hemorajik şok geçiren çocuklarda kan bileşenleri ile yapılan resüsitasyonda, plazma eksikliğini en aza indirmek için yüksek plazma:eritrosit oranlarını (1:1) hedeflemeyi öneriyoruz.

Using LTOWB instead of individual blood components in children more rapidly provides RBCs, plasma and platelets to children with severe traumatic bleeding, more effectively resolves shock and coagulopathy,[23] is associated with less total amount of blood products administered and mechanical ventilation days,[24] and is independently associated with increased 72 hour (OR 0.23; [0.08–0.70]), and 28 day mortality (OR 0.41; [0.23–0.98]) in a single center retrospective study.[8]

Adult data indicates the use of LTOWB compared to individual blood components is independently associated with improved 24 hour and 28 day survival and is also associated with less (40–60%) total blood products administered.[25–27] Data from studies performed on children and adults suggest no increased risk of hemolysis in non-group O recipients and no increase in any other adverse outcomes to include organ failure.[28–30]

1.3: In traumatically injured children in hemorrhagic shock, when utilizing blood component resuscitation, we suggest targeting high plasma:RBC ratios (1:1) to minimize the plasma deficit. *Consensus Panel Expertise, 100% agreement (n=16), median 9, IQR: 8–9.*

3.1: Travmatik yaralanma sonucu hemorajik şok geçiren çocuklarda, yaralanmadan sonraki 3 saat içinde traneksamik asidin ampirik olarak kullanılması düşünülebilir.

The transfusion of blood products by out-of-hospital EMS providers is feasible and safe.[48, 49] Data show that the LTOWB[49], red blood cells and plasma[48] under pediatric dosing protocols is feasible, acceptable to providers, and not associated with adverse transfusion-related events.[50] Only two studies have compared outcomes between matched pediatric cohorts who received blood products prehospital versus in-hospital. These studies are limited by sample size and moderate bias due to outcome measurement and confounding.[50, 51] Though the studies were not adequately powered to detect a difference in mortality; authors did report that the prehospital transfusion groups did receive less in-flight crystalloid, had higher admission fibrinogen levels, and faster time to normalization of the international normalized ratio (INR).[51] This recommendation has to take into account the ability of blood products and comfort level of the practice of regional Emergency Medical Services. However, the above literature suggests that there is evidence that this can be organized and safely utilized in pediatric trauma patients with hemorrhagic shock.

3) Use of tranexamic acid and other hemostatic adjuncts in pediatric traumatic hemorrhagic shock—3.1: In traumatically injured children with hemorrhagic shock, the empiric use of tranexamic acid within 3 hours of injury might be considered. *Clinical Recommendation, conditional recommendation, very low certainty of evidence, 80% agreement (n=15), median 7, IQR: 7–8.*

2018 DCR

REVIEW

Damage control resuscitation in pediatric trauma

Meghan Gilley and Suzanne Beno

Purpose of review
Damage control resuscitation is an overall management strategy used in trauma patients to rapidly restore physiologic stability, while mitigating hypothermia, coagulopathy and acidosis. We review the evidence and current practice of damage control resuscitation in pediatric trauma patients with a specific focus on fluid management.

Recent findings
There have been a number of studies over the last several years examining crystalloid fluid resuscitation, balanced blood product transfusion practice and hemostatic agents in pediatric trauma. Excessive fluid resuscitation has been linked to increased number of ICU days, ventilator days and mortality. Balanced massive transfusion (1 : 1 : 1 product ratio) has not yet been demonstrated to have the same mortality benefits in pediatric trauma patients as in adults. Similarly, tranexamic acid (TXA) has strong evidence to support its use in adult trauma and some evidence in pediatric trauma.

Summary
Attention to establishing rapid vascular access and correcting hypothermia and acidosis is essential. A judicious approach to crystalloid resuscitation in the bleeding pediatric trauma patient with early use of blood products in keeping with an organized approach to massive hemorrhage is recommended. The ideal crystalloid volumes and/or blood product ratios in pediatric trauma patients have yet to be determined.

Keywords
damage control resuscitation, massive transfusion protocol, pediatric trauma

INTRODUCTION

Trauma is the leading cause of morbidity and mortality in children [1,2]. Blunt craniocervical trauma is the most common cause of death in pediatric patients; however, hemorrhage remains a leading cause of preventable death. Damage control resuscitation (DCR) is a management strategy widely used in adult trauma resuscitation to attempt to avoid the lethal triad of hypothermia, acidosis and coagulopathy [3,4▪,5,6]. This strategy has evolved over the past decade, but dates back to World War II when whole-blood transfusion was recommended based on the concept that both shock and coagulopathy needed to be addressed for optimal patient outcomes [7]. DCR today consists of immediate hemorrhage control, limited use of crystalloid fluids, early use of warmed blood products, considerations in the application of these strategies, as the adolescent patient has different anatomy, physiology and mechanisms of trauma than the young child.

CASE 1

A 5-year-old girl was struck by a car traveling at 65 km/h and thrown 10 ft away. Upon paramedic arrival, the child had a Glasgow Coma Scale (GCS) of 14, heart rate (HR) of 150 and a blood pressure (BP) of 85/60. She arrives to the emergency department (ED) immobilized with a cervical spine collar on a backboard with one intravenous line. You note bruising on her abdomen and suspect intra-abdominal injury as well as a pelvic fracture given

lished massive hemorrhage protocol, only eight of 13 patients received plasma and platelets in the first 24 h.

In summary, MTPs expedite access to PRBCs and other blood products, and have shown clear mortality benefit in adults [3,23,24]. Although this evidence for mortality reduction is not yet present in pediatric trauma, it is strongly recommended that pediatric institutions have MTPs available to organize and expedite product delivery [29▪,33,34]. In addition, although it makes physiologic sense to take a 'balanced' approach to the resuscitation of a child in traumatic hemorrhagic shock, evidence does not currently suggest that the 1 : 1 : 1 ratio is ideal. Further research is necessary to clarify blood product ratios in pediatric trauma.

TRANEXAMIC ACID

In adult trauma, tranexamic acid (TXA) is now a cornerstone of hemostatic resuscitation with strong supporting evidence in mortality reduction if used early [35,36▪]. TXA is an antifibrinolytic agent that reversibly binds to plasminogen, preventing the degradation of fibrinogen and promoting clot stability. TXA in trauma is estimated to save one in 67 lives [35]. Evidence regarding the use of TXA in TBI is pending the results of the CRASH 3 trial and other ongoing studies [37].

Data in pediatric trauma patients is more limited, with the majority of pediatric literature documenting the use and benefit of TXA in spinal, craniofacial and cardiac surgeries [38–41]. Nishijima *et al.* [42▪] reviewed TXA use across US Childrens' Hospitals from 2009 to 2013 and found 0.31% use in trauma. The PED-TRAX study retrospectively reviewed pediatric patients injured in Afghanistan from 2008 to 2012, in which 66 (9%) of 766 children received TXA. When adjusted for demographics, injury type, severity, vitals and laboratory parameters, TXA was independently associated with decreased mortality without significant increase in thromboembolic events. In addition, patients receiving large volume transfusion with TXA had improved neurological outcomes [41]. Although data to support widespread use in pediatric trauma remains limited, widespread use in other clinical situations and preliminary evidence in trauma is suggestive of benefit with minimal harm or cost. As of 2017, TXA requires further investigation in

resuscitation. It is reasonable to consider TXA in pediatric trauma, and to administer TXA within the first 3 h of presentation if actively bleeding and requiring blood products [43].

PERMISSIVE HYPOTENSION

Permissive hypotension is a resuscitation strategy based upon observations that trauma patients with uncontrolled hemorrhagic shock worsen with intravenous fluid resuscitation, likely related to coagulopathy and hemodilution, but also to destabilization of the clot with increased hydrostatic pressure [21]. Permissive hypotension as a resuscitative strategy balances an acceptable amount of hypotension with end-organ ischemia and hypoxia until surgical or interventional control of the bleeding can be established, essentially tolerating a palpable pulse and mentation as opposed to resuscitating to a normal BP. Permissive hypotension has most benefit in specific scenarios, such as hemorrhage from an arterial source. It is controversial and not recommended in patients with concomitant head injuries [44▪].

There is no evidence supporting the use of permissive hypotension in pediatrics. In addition, there is significant concern for use of this strategy based on the understood physiologic response pediatric patients have to hypovolemia; children's ability to increase HR and utilize peripheral vasoconstriction to maintain BP means that hypotension is a late sign of shock and represents a critical and uncompensated state [4▪,21]. Permissive hypotension for young children is therefore not currently recommended due to lack of evidence, physiologic considerations and high rates of concomitant TBI. Certain clinical scenarios may challenge this view point: specifically the adolescent population is more similar in physiology to adults, and therefore, management strategies may include permissive hypotension. There can be nuanced approaches to utilizing this DCR strategy in pediatric trauma.

ROTATIONAL THROMBOELASTOMETRY/ THROMBOELASTOGRAPHY

Viscoelastic hemostatic assays (VHA) such as rotational thromboelastometry (ROTEM) and thromboelastography (TEG) are functional assays that provide rapid information regarding clot formation,

1040-8703 Copyright © 2018 Wolters Kluwer Health, Inc. All rights reserved.

Damage-Control Resuscitation

- Hasar kontrol resüsitasyonu (DCR); kanamanın hızla kontrol altına alınması; hemodilüsyon, asidoz ve hipotermiden kaçınılması; eritrosit, plazma ve trombositler (veya mevcutsa tam kan) ile erken dönemde ampirik ve dengeli transfüzyon yapılması ve endike olduğunda intravenöz ya da mekanik hemostatik yardımcı yöntemlerin kullanılması süreçlerini kapsar.

WHAT YOU NEED TO KNOW SERIES – REVIEWS

Damage-control resuscitation in pediatric trauma: What you need to know

Robert T. Russell, MD, MPH, Christine M. Leeper, MD, *and* Philip C. Spinella, MD, *Birmingham, Alabama*

ABSTRACT: Damage-control resuscitation (DCR) consists of rapid control of bleeding, avoidance of hemodilution, acidosis, and hypothermia; early empiric balanced transfusions with red blood cells, plasma and platelets, or whole blood when available, and the use of intravenous or mechanical hemostatic adjuncts when indicated. The principles used in pediatric and adult trauma patients are quite similar. There are very important recognized physiologic differences in children with traumatic hemorrhagic shock that warrant slight variations in DCR. In pediatric trauma patients, early physiologic signs of shock may be different from adults and the early recognition of this is critical to enable prompt resuscitation and utilization of damage control principles. This review details the current principles of pediatric DCR based on the best available literature, expert consensus recommendations, and also describes a practical guide for implementation of DCR strategies for pediatric trauma patients. (*J Trauma Acute Care Surg.* 2023;95: 472–480. Copyright © 2023 Wolters Kluwer Health, Inc. All rights reserved.)

KEY WORDS: Pediatric trauma; resuscitation; transfusion; whole blood; hemorrhagic shock.

Hasar Kontrol Resüsitasyonu

- Hipotermi, koagülopati ve asidozu hafifletmek için kullanılan yöntemler.

- Hasta kanının pıhtı oluşturma yeteneğini korumayı amaçlar.

Hasar Kontrol Resüsitasyonu

- Kristaloid sıvıların sınırlı kullanımı,
- İzin verilen hipotansiyon,
- Isıtılmış kan ürünlerinin erken kullanımı,
- Dengeli masif transfüzyon protokolleri,
- Hemostatik ajanların kullanımı ve,
- Hasar kontrolü cerrahisinden oluşmaktadır.

Dengeli Resüsitasyon Stratejisi (ATLS 2025)

- Başlangıçta 20 mL/kg'lık izotonik kristaloid bolusu ve sonrasında,
- Nabız hızı, kan basıncı, mental durum ve cilt perfüzyonu kontrol edilir.
- Pediatrik masif transfüzyon protokolünün (MTP) bir parçası olarak 10-20 mL/kg paketlenmiş kırmızı kan hücresi ve, 10-20 mL/kg taze dondurulmuş plazma ve trombosit ile
- Kiloya dayalı Tam Kan.

Sıvı Resüsitasyonuna Dört Yanıt

1. Çoğu çocuğun durumu yalnızca kristaloid sıvı kullanılarak stabilize edilir ve kan gerekmez; "erken yanıt verenler"
2. Bazı çocuklar kristaloid ve kan resüsitasyonuna yanıt verirler; "yanıt verenler".
3. Bazı çocuklar kristaloid sıvıya ve kana ilk yanıtı verir ancak daha sonra kötüleşme meydana gelir; "geçici yanıt verenler". Bu çocuklarda muhtelemen kanama hala devam etmektedir.
4. Diğer çocuklar kristaloid sıvıya ve kan infüzyonuna yanıt vermez; "yanıt vermeyenler". Bu çocuklar genellikle hızlı kanar.

Sıvı Resüsitasyonuna Dört Yanıt

- Geçici yanıt verenler ve yanıt vermeyenler maling transfüzyon protokolünün (MTP) etkinleştirilmesi ve
- Erken operasyon için adaylardır.

Kan Replasmanı

- Hasta kristaloide anlamlı bir yanıt vermez ve hemodinamik stabilite sağlanamazsa; ek kristaloid yerine
- O- (veya erkek çocuklarda O+) taze kan tercih edilir.
- Kanamadan şüpheleniliyorsa, kanamanın toplam kanın %40'ı kadar olduğu düşünülüyorsa ve kan halihazırda mevcutsa, replasmana kristaloid yerine, 10 mL/kg paketlenmiş ES veya tam kanla başlanılabilir.

ORAN ?

- Pediatrik travmada kan ürünü oranlarını açıklığa kavuşturmak için daha fazla araştırmaya ihtiyaç vardır.
- Ayrıca, travmatik hemorajik şoktaki bir çocuğun resüsitasyonunda 'dengeli' bir yaklaşım benimsemek mantıklı olsa da, mevcut kanıtlar 1:1:1 oranının ideal olduğunu göstermemektedir.

Author Manuscript
Author Manuscript
Author Manuscript

HHS Public Access
Author manuscript
J Trauma Acute Care Surg. Author manuscript; available in PMC 2024 January 01.

Published in final edited form as:
J Trauma Acute Care Surg. 2023 January 01; 94(1): S2–S10. doi:10.1097/TA.0000000000003805.

Pediatric Traumatic Hemorrhagic Shock Consensus Conference Recommendations

Robert T. Russell, MD, MPH[1], Joseph R. Esparaz, MD, MPH[1], Michael A. Beckwith, MD[2], Peter J. Abraham, MD[3], Melania M. Bembea, MD, PhD, MPH, PhD[4], Matthew A. Borgman, MD[5], Randall S. Burd, MD, PhD[6], Barbara A. Gaines, MD[7], Mubeen Jafri, MD[8], Cassandra D. Josephson, MD[9], Christine Leeper, MD[10], Julie C. Leonard, MD, MPH[11], Jennifer A. Muszynski, MD, MPH[12], Kathleen K. Nicol, MD[13], Daniel K. Nishijima, MD, MAS[14], Paul A. Stricker, MD[15], Adam M. Vogel, MD[16], Trisha E. Wong, MD, MS[17], Philip C. Spinella, MD[18]

[1]Department of Surgery, Division of Pediatric Surgery, University of Alabama at Birmingham, Children's of Alabama, Birmingham, AL

[2]Department of Surgery, Division of Pediatric Surgery, University of Michigan, Ann Arbor, MIS

[3]Department of Surgery, University of Alabama at Birmingham, Birmingham, AL

[4]Division of Anesthesiology and Critical Care Medicine, Johns Hopkins University School of Medicine, Baltimore, MD

[5]Department of Pediatrics, Brooke Army Medical Center, Uniformed Services University

[6]Division of Trauma and Burn Surgery, Children's National Hospital, Washington, DC

[7]Department of Surgery, University of Pittsburgh School of Medicine, UPMC Children's Hospital, Pittsburgh, PA.

[8]Division of Pediatric Surgery, Doernbecher Children's Hospital, Oregon Health and Science University, Portland, OR

[9]Departments of Pathology and Laboratory Medicine and Pediatrics, Emory University School of Medicine, Atlanta, GA

Düşük Titreli Tam Kan (LTOWB) Kullanımı

- Pediatrik Travmatik Hemorajik Şok Konsensüs Konferansı önerileri, hemorajik şoktaki travma mağduru çocukların resüsitasyonunda tam kanın mevcut olması durumunda kullanımını desteklemektedir.
- %33 **daha az antikoagülan ve koruyucu madde içermesi**
- Daha yüksek hemoglobin ve trombosit konsantrasyonları ile **pıhtılaşma faktörü** seviyeleri,
- Daha az dilüsyonel koagülopati, daha az hipokalsemi , daha az kan ürünü kullanımı.
- Daha işlevsel hamostatik Trombositler.
- LTOWB'nin daha yaygın kullanımının önündeki bir kısıtlılık, RhD-LTOWB'nin bulunabilirliğidir. RhD-LTOWB kullanımı, RhD tipi henüz bilinmeyen kız çocuklarında, gelecekte ortaya çıkabilecek bir fetüs ve yenidoğan hemolitik hastalığı (HDFN) komplikasyonu riskini önlemek açısından avantajlıdır.

Traneksamik Asit (TXA)

- TXA, plazminojenin plazmine dönüşmesini önleyerek fibrinolizi yavaşlatır, fibrin pıhtılarını stabilize eder ve kanamayı en aza indirir.
- **Traneksamik Asit (TXA):** Erken dönemde (ilk 3 saatte) TXA kullanımı mortaliteyi azaltmaktadır.

1995 -2025 tarihleri arasında yayınlanmış, çocuklarda (0-18 yaş) TXA'nın etkinliği (9 çalışma)

TXA, pediatrik hemorajik acil durumlarda hayatta kalma oranını ve klinik sonuçları iyileştirmek için kritik bir müdahale olmaya devam etmektedir.

JPPT | Review

Tranexamic Acid in Pediatric Care: A Comprehensive Overview

Mohammed Alsabri, MD, FAAP; Mayar M Aziz, MBBS; Karim Fahmy, MD; Alaa Zayed, MD; Mohamed Tawfik Elkefl, MBBS; Ebraheem A. Ebraheem, MBBS; and Menna S. Nabawy, MBBS

OBJECTIVE Tranexamic acid (TXA) is a vital hemostatic agent in pediatric medicine, demonstrating substantial efficacy in managing both traumatic and nontraumatic hemorrhage. Although TXA has been widely adopted in adult trauma and surgical care, reducing mortality, minimizing transfusion requirements, and controlling perioperative and emergency-related bleeding, its pediatric use remains under researched, with knowledge gaps in optimal dosing, long-term safety, and thromboembolic risks. Pediatric-specific clinical guidelines remain inconsistent, necessitating further research on their role in pediatric emergency and perioperative care.

METHODS A targeted literature search using a combination of MeSH terms and keywords was conducted using PubMed and Google Scholar, covering relevant studies focusing on the efficacy, pharmacokinetics, dosing strategies, and safety profile of TXA in children (ages 0–18 years) published between 1995 and February 2025.

RESULTS Evidence supports the efficacy of TXA in reducing blood loss, minimizing transfusion needs, and improving survival outcomes in pediatric trauma, surgery, and emergency settings. Alternative administration routes, such as nebulized TXA, show promise for post-tonsillectomy hemorrhage and refractory epistaxis, potentially reducing the need for invasive interventions. However, gaps persist regarding age-specific pharmacokinetics, long-term safety, and potential thromboembolic and seizure risks. Inconsistent clinical practice, limited provider familiarity, and a lack of standardized pediatric protocols further hinder the use of TXA in pediatric settings.

CONCLUSION TXA remains a critical intervention for improving survival and clinical outcomes in pediatric hemorrhagic emergencies. However, its full potential depends on further interdisciplinary research, the development of standardized pediatric-specific guidelines, and enhanced provider training. Addressing knowledge gaps will be essential to ensuring safe implementation of TXA across diverse pediatric clinical scenarios.

ABBREVIATIONS CPB, cardiopulmonary bypass; CRASH-2, The Clinical Randomization of an Antifibrinolytic in a Significant Hemorrhage; EEG, electroencephalography; IV, intravenous; MATTERs, Military Application of Tranexamic Acid in Trauma Emergency Resuscitation; TXA, tranexamic acid;

KEYWORDS tranexamic acid; pediatric care; hemostasis; trauma; hemorrhage; antifibrinolytic

J Pediatr Pharmacol Ther 2026;31(1):18–29

DOI: 10.5863/JPPT-25-00027

Pediatrik travma vakalarında, mortalitede önemli bir azalma ile ilişkili olduğu gösterilmiştir.

blood loss in cardiac and major orthopedic procedures, while reducing the need for allogeneic blood transfusions in elective surgeries in adults. [2,3]

TXA plays an increasingly vital role in pediatric emergency medicine, particularly in the management of traumatic and nontraumatic bleeding. It has demonstrated a capacity to reduce hemorrhage, lower transfusion requirements, and improve survival rates in trauma patients.[4,5] In pediatric trauma cases, TXA administration has been independently associated with a substantial reduction in mortality without an increased incidence of thromboembolic complications.[4–6] A multicenter study reported prehospital administration of TXA to 36.6% of severely injured pediatric patients, with a median single intravenous (IV) bolus dose of 16 mg/kg and no reporting on the maintenance doses. Only 51.8% of patients met the criteria for receiving TXA.[6] In the United States, 35% of pediatric trauma centers reported routine TXA use, primarily in cases of hemodynamic instability or severe hemorrhage.[7] Additionally, in perioperative settings, TXA has demonstrated efficacy in reducing blood loss and transfusion requirements in children undergoing major procedures such as craniotomies and high-risk surgeries.[8,9]

TXA exhibits an overall favorable safety profile in pediatric populations; however, a few notable adverse events warrant careful consideration. Seizures remain a major concern, with studies reporting an elevated risk in pediatric trauma and cardiac surgery patients.[10,11] There has also been a fatal case of status epilepticus linked to TXA administration in a noncardiac surgical setting.[12] Furthermore, a systematic review and meta-analysis found no evidence of an increased risk of thromboembolic events such as deep venous thrombosis or pulmonary embolism.[13] Renal impairment is uncommon with TXA, with limited reports of adverse renal events and no consistent findings in pediatric populations.[13]

February 2025. The search focused on the role of TXA in pediatric trauma, perioperative care, and emergency medicine, emphasizing its efficacy, pharmacokinetics, safety profile, and alternative routes of administration.

A literature search was conducted in PubMed using MeSH and free-text keywords related to TXA and pediatric care. MeSH terms included tranexamic acid, antifibrinolytic agents, hemorrhage, wounds and injuries, blood transfusion, surgical procedures, operative, pediatrics, infant, child, and adolescent. Keywords included "tranexamic acid," "TXA," "pediatric bleeding," "pediatric trauma," "perioperative bleeding," and "postoperative hemorrhage." Searches were limited to English-language studies involving children and adolescents (0–18 years) published in peer-reviewed journals.

Pharmacology of Tranexamic Acid. ***Pharmacodynamics.*** TXA is a synthetic lysine derivative with potent antifibrinolytic activity. Its pharmacodynamic actions include stabilizing clots by preventing fibrinolysis. It inhibits plasminogen activation in a competitive, reversible manner by binding to multiple sites, including 4 or 5 low-affinity sites and 1 high-affinity site critical for fibrin interaction. TXA prevents plasminogen from converting to plasmin, thereby slowing fibrinolysis, stabilizing fibrin clots, and minimizing bleeding.[14,15] At higher doses (>50 mg/kg), it noncompetitively inhibits plasmin activity similarly to aminocaproic acid, but with 10-fold greater potency, longer half-life, and duration of action. It also exhibits lower risk for myopathy, rhabdomyolysis, and gastrointestinal side effects, making it associated with a more favorable safety and tolerability profile than aminocaproic acid and more suitable, especially in trauma patients.[14,15] However, TXA is widely distributed throughout the body, including the central nervous system, where off-target antagonism of γ-aminobutyric acid type A receptors may lead to neuronal hyperexcitability and seizures, especially when given improperly or during

DOZ

PED-TRAX (Pediatrik Travma ve Traneksamik Asit Çalışması) retrospektif incelemesi, 18 yaş ve altındaki hastalarda TXA'nın etkisini değerlendirmeyi amaçlamıştır

Dikkat çekici olan, çalışmanın tüm pediatrik yaş gruplarında standart yetişkin TXA dozunu (10 dakikada 1 g, 8 saatte 1 g) kullanmasıdır

Kraliyet Pediatri ve Çocuk Sağlığı Koleji, 12 yaş ve üzeri hastalar ile 12 yaşından küçük hastalar arasında ayrım yaparak, yaşa dayalı TXA dozlaması önermektedir.

12 yaş ve üzeri hastalar yetişkin dozlamasıyla tedavi edilir (10 dakika boyunca 1 g, ardından 8 saat boyunca 1 g infüzyon).

Daha küçük hastalar için, ağırlığa dayalı dozlama tercih edilir: 10 dakika boyunca uygulanan, 15 mg/kg'lık yükleme dozu (maksimum 1 g). Daha sonra, kanama durana kadar veya en az 8 saat boyunca 2 mg/kg/saatlik idame infüzyonuna devam edilir.

and MATTERs trials, demonstrating reduced mortality in pediatric trauma patients who received TXA. However, the study also noted deaths from traumatic brain injury, raising questions about whether TXA contributed to cerebral edema or seizures. Other reported side effects included acute kidney injury and venous thromboembolism.[28] Despite these concerns, the role of TXA in these complications remains unclear, given the substantial burden of injury in trauma patients. Of note, TXA use did not significantly reduce blood product requirements (p <0. 09), a finding warranting further investigation.

In contrast to the extensive adult trauma data, pediatric-specific TXA trials remain scarce. However, perioperative studies have provided critical insights into the pharmacokinetics and potential adverse effects of TXA in pediatric populations. TXA has also been investigated in pediatric traumatic hyphemia management, further demonstrating its hemostatic benefits.[29]

Pediatric-Specific Data: PED-TRAX and Beyond. Following the CRASH-2[24,25] and MATTERs[27] trials, the PED-TRAX (Pediatric Trauma and Tranexamic Acid study) retrospective review sought to evaluate the impact of TXA in patients aged 18 years and younger.[4] Of note, the study used the standard adult TXA dose across all pediatric age groups (1 g over 10 minutes, 1g over 8 hours).[4] PED-TRAX findings aligned with adult trauma data, reporting significant improvements in neurological status (p < 0.01) and reduced ventilatory dependence (p

(age-adjusted), open/multiple fractures, and significant soft tissue injuries.[20,32]

The Royal College of Pediatrics and Child Health recommends age-based TXA dosing, distinguishing between patients 12 years and older and those younger than 12 years. Patients 12 years of age and older are treated with adult dosing (1 g over 10 minutes, followed by a 1 g infusion over 8 hours). For younger patients, weight-based dosing is preferred as follows: a 15-mg/kg loading dose (maximum 1 g) diluted in sodium chloride 0.9% or glucose 5%, administered over 10 minutes. A maintenance infusion of 2 mg/kg/hr is then continued for at least 8 hours or until bleeding ceases.[20] The recommended dilution for maintenance infusion is 500 mg in 500 mL of sodium chloride 0.9% or glucose 5%, delivered at a rate of 2 mL/kg/hr.[20]

The Role of Tranexamic Acid in Procedural Hemostasis

TXA application in procedural hemostasis within the emergency department for pediatric patients has gained increasing attention, particularly in trauma and invasive procedures.[32] In the emergency department, TXA is often employed to control acute hemorrhage during procedures such as laceration repair, nasal packing for epistaxis, and dental or oral injuries. Administered topically (5% solution via soaked gauze or rinse),[29,34] or IV (15 mg/kg)[20] as a single 1-time dose, TXA has been shown to effectively reduce bleeding while

Termoregülasyon
ATLS 2025

- Hipotermi, bir çocuğun tedaviye verdiği yanıtı önemli ölçüde tehlikeye atabilir, pıhtılaşma sürelerini uzatabilir

- Aktif ısıtma ve ısıtılmış intravenöz sıvıların uygulanması.

Non-Operatif Yönetim (NOM)

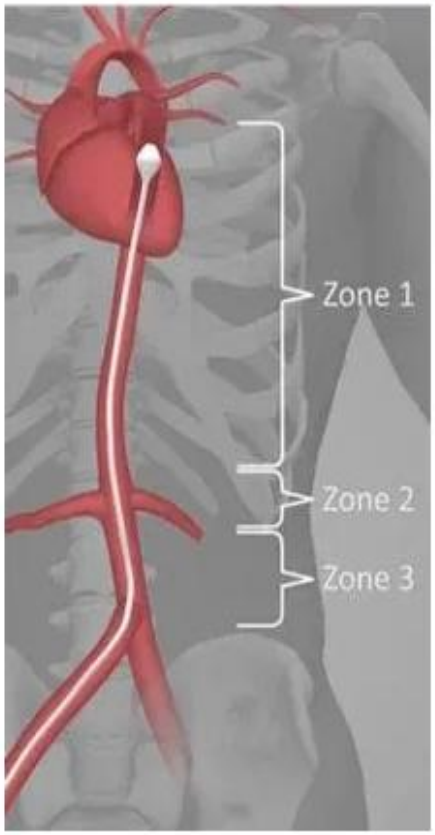
- Dünya çapında hemodinamik açıdan stabil çocuklarda ameliyatsız tedavi yöntemlerine doğru paradigma değişimi vardır.
- Pediatrik künt batın travmalarında (dalak ve karaciğer yaralanmaları dahil) hemodinamik olarak stabil hastaların %90'ından fazlası ameliyatsız (non-operatif) takip edilir.
- Periton irritasyon bulgularının (defans, rebound) olmaması.
- Hastanın hemodinamik olarak stabil olması veya minimal resüsitasyonla stabil kalması.
- Cerrahi olmayan yöntemlerle kanamanın kontrolü, DCR'nin temel bir bileşenidir.

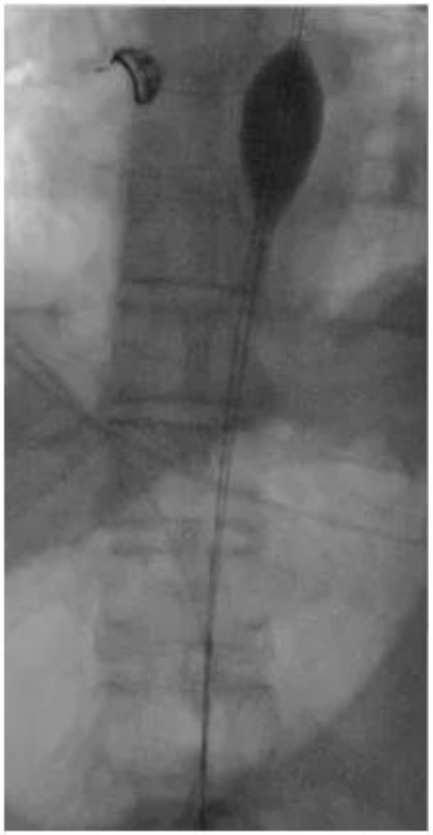
REBOA
(Aortanın Resüsitatif Endovasküler Balon Oklüzyonu)

- Erişkinlerde kullanım yaygınlaştı.
- Çocuk hastalarda anatomik sınırlar ve klinik kanıt yetersizliği nedeniyle kısıtlı ! ve dikkatli uygulanmalıdır.
- Ağır yaralanmış hastaların yaklaşık yüzde yirmisi REBOA'dan potansiyel olarak fayda görebilir ve yetişkinlerle yapılan çalışmalara benzerdir.

REBOA

Balon, yaralanmanın yerine bağlı olarak Bölge I'de (inen torasik aort) veya Bölge III'te (infrarenal aort) şişirilir.





4-7 Fr Kateter Çapları ve Gruplar

Balloons for Kids: Anatomic Candidacy and Optimal Catheter Size for Pediatric Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA)

Retrospective review of 557 pediatric CT scans (Feb 2016 – Oct 2019)

↓

Two investigators obtained vascular measurements

↓

Measurements grouped into Broselow category by patient height

Recommended Pediatric REBOA Catheter Size by Broselow category

	Yellow 12-14 kg 85-98 cm	White 15-18 kg 98-110 cm	Blue 19-23 kg 110-121 cm	Orange 24-29 kg 121-133 cm	Green 30-36 kg 133-147 cm	Black >36 kg ≥ 147 cm
Common Femoral Artery Diameter, mm	3.3	3.8	4.1	4.5	4.9	6.0
Recommended REBOA Catheter Size (Fr)	4	4	4	7	7	7

Sykes et al. *Journal of Trauma and Acute Care Surgery.* Jan 2021

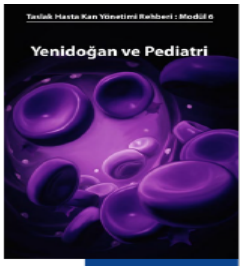
@JTraumAcuteSurg

Copyright © 2021 Wolters Kluwer Health, Inc. All rights reserved

The Journal of Trauma and Acute Care Surgery®

Kritik Kanama Protokolü

"Türkiye'de Kan Transfüzyon Yönetim Sisteminin Geliştirilmesi için Teknik Yardım Projesi“ 2021



Bu proje Avrupa Birliği ve Türkiye Cumhuriyeti tarafından finanse edilmektedir.
Türkiye'de Kan Transfüzyon Yönetim Sisteminin Geliştirilmesi için Teknik Destek - EuropeAid/139230/IH/SER/TR
Sözleşme No: TREESP3.1.IBTMST/P-01-01

Kurumlar, aşağıdaki hususları dikkate alan yenidoğan ve pediatrik hastalara özgü bir kritik kanama protokolü geliştirmelidir:

- ne zaman etkinleştirileceğine ilişkin rehberlik
- kiminle temasa geçileceği ve onlarla nasıl temasa geçileceği (ilgili telefon numaraları)
- roller ve sorumluluklar
- mümkünse geniş lümenli kanüller kullanmak gibi güvenlik önlemleri
- yaş veya ağırlık ayarlı:
  - masif kanama protokollerinin içeriği
  - kullanılan kan bileşenlerinin miktarları veya dozları
- İlk, ikinci ve sonraki basamaklara dahil edilecek bileşenlerin tanımı (örneğin, eritrosit konsantresi, TDP, trombosit konsantresi ve kriyopresipitat)
- kriyopresipitat kullanımının zamanlamaları veya zamanlaması
- Viskoelastik HBT (TEG / ROTEM) kullanıldığında, rolünün tanımı
- İlgili iletişim bilgileri ile masif kanama protokolünün devre dışı bırakılması için sorumlulukların tanımlanması.

Kritik kanama protokolünün başlatılması için önerilen kriterler

- 4 saatten az süre içinde oluşmuş veya beklenen >35-40 ml/kg kan kaybı + hemodinamik olarak stabil değil, ±kanamanın devamı bekleniyor.
- Ciddi göğüs, batın, pelvis veya multiple uzun kemik travması veya kafa travması
- Majör gastrointestinal veya cerrahi kanama

Hasar kontrol resüsitasyonu

- Nedeni belirleyin ve kanamayı hızla kontrol altına alın
  - Baskı, bandaj ve turnike
  - Erken cerrahi değerlendirme ve girişim
  - Gerekirse anjiografi
- Normal koagülasyonu sağlayın ve idame edin
- Hipotermiden sakının (aktif ısıtan önlemler kullanın)
- Aşırı kristaloidden sakının
- Kanama kontrol altına alınana kadar kontrollü hipotansiyon uygulayın
- Transfüzyon eşiği olarak sadece hemoglobin kullanmayın

Kan kurtarma

Uygun olduğunda kan kurtarma tekniklerini kullanmayı düşünün

Doz

İsrafı en aza indirmek için her ünitenin kullanımını optimize edin

EK	20–25 mL/kg
Trombosit sayısı <50 × 10^9/L	Trombosit 10–15 mL/kg
PZ/aPTZ >1.5 × normal	TDP 15 mL/kg[a]
Fibrinojen <2 g/L	Kriyopresipitat 5 mL/kg[a]
Traneksamik asit	Yükleme dozu 15 mg/kg (maks. 1 g) 10 dak. sonra 2 mg/kg/saat infüzyon 8 veya daha fazla saat veya kanama durana kadar

[a] mevcut preparatların dozunu tavsiye etmek için lokal transfüzyon merkezi

aPTT, aktive parsiyel tromboplastin zamanı; EK, eritrosit konsantresi; HBT, hasta başı testi; PCC, protrombin kompleks konsantresi; PZ, protrombin zamanı; rFVIIa, aktive rekombinan fakötr VII; TDP, taze donmuş plazma

Hipofibrinojeneminin önlenmesi

- Aşırı kanamada fibrinojen düzeyleri diğer faktörlerden daha fazla düşer.
- Dilüsyon ve hiperfibrinoliz (örn. travmada) düzeyi daha da düşürür.
- Kritik kanamada, fibrinojeni >2 g/L düzeyinde tutmak önerilir.
- Protokole fibrinojen replasmanının kullanımı ve zamanlaması için rehberliği; bu rehberlik viskoelastometrik HBT içerebilir, ekleyin.

Özel klinik durumlar

Warfarin:
- vitamin K, PCC/TDP ekleyin

Kafa travması:
- trombosit sayısı >100 × 10^9/L hedefleyin
- izin verilen hipotansiyon kontrendike

rFVIIa kullanımını göz önünde bulundurun[a]

Erişkinlerde yapılan çalışmalardan elde edilen kanıtlara dayanarak, travma hastalarında rFVIIa'nın rutin kullanımı önerilmemektedir. Bununla birlikte, kurumlar aşağıdakilerin geçerli olduğu durumlarda rFVIIa kullanımı için bir süreç geliştirmeyi seçebilir :

- kurtarılabilir hastalarda kontrolsüz kanama ve
- kanamayı kontrol altına almada başarısız cerrahi veya radyolojik önlemler ve
- yeterli kan bileşeni replasmanı ve pH >7.2, ısı >34°C. Ancak kanama devam ediyor ise

Dozu Hematoloji veya transfüzyon uzmanı ile tartışın.

[a] rFVIIa bu durumda kullanım için lisanslı değildir.

Sonuç

- Pediatrik travmanın değerlendirilmesi ve yönetiminde çocukların kendine özgü anatomik ve fizyolojik özelliklerinin dikkate alınması gereklidir.
- Çocuklarda hipotansiyon gelişmeden önce şoku tanımak hayat kurtarır.
- Taşikardi ve zayıf nabız, hipovoleminin erken tanınmasında ve çocuklarda sıvı resüsitasyonuna erken başlama ihtiyacında en önemli belirteçlerdir.
- İlk basamak 20 mL/kg kristaloittir; yanıtsızlık durumunda gecikmeden 10 mL/kg eritrosit süspansiyonuna ve MTP protokolüne geçilmelidir.
- Pediatrik batın travmalarında temel hedef, hemodinamik stabilizasyonu sağlayarak hastayı ameliyatsız (non-operatif) yöntemlerle başarıyla tedavi etmektir.