

Updates in Pediatric Trauma

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Hemorrhage : leading cause of preventable death in pediatric trauma

- Multisystem injuries in children may lead to significant blood loss
- Pediatric patients have higher physiologic reserve – maintain SBP longer
 - Blood pressure may remain normal until 40-50% of blood volume lost
- Tachycardia is often the first sign of shock
- Other signs
 - Narrowed pulse pressure
 - Oliguria
 - Poor capillary refill/cool extremities
 - Decreased level of consciousness

OBTAIN ADEQUATE IV ACCESS IMMEDIATELY

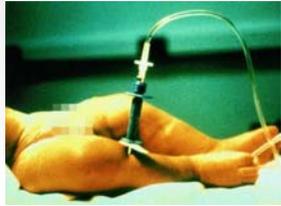
Outline

- What's new: Pediatric Massive Transfusion
 - MT definition in pediatrics
 - Use of massive transfusion protocols
 - Use of TEG in pediatric trauma
 - Role of tranexamic acid (TXA)
 - What about Factor VIIa?



Intraosseous access – consider after 90 seconds of unsuccessful PIV placement

- Tibial plateau is most common site
- Long track record for safety
- Few contraindications
- Low complication rate
- Attempt PIV within 3-4 hrs



<http://emedicine.medscape.com/article/940993>

Pediatric Trauma Pearls - review

- Trauma - #1 cause of death in children over age 1
- 2nd leading cause in infants
- 80% of pediatric trauma victims will have an associated head injury
 - 70% of trauma deaths are due to head injury
- Hemorrhage – leading cause of preventable death
- Blunt trauma accounts for ≈ 80-90% of injuries





Cook-type IO needle



Cook-type screw-tip IO (Sur-Fast)



EZ-IO (Vidacare) insertion drill with 3 needle sizes

<http://emedicine.medscape.com/article/940993>

Pediatric Massive Transfusion: Current Practice

Cote et al. Practice of Anesthesia for Infants and Children, 5th ed. 2013

- Massive Transfusion – considered when patient loses one blood volume
- Dilutional coagulopathy of massive blood transfusion is reasonably predictable
 - When PRBC's used: clotting factors and platelets may be diluted after 1 blood vol lost
- Only a guide – PT, PTT, fibrinogen and platelet count should be used to guide transfusion

Component	Dose	Effect
PRBC's	10-15mL/kg	↑ Hgb 2-3 g/dL
Platelets	5-10mL/kg	↑ Plt 50-100K/mm ³
FFP	10-15mL/kg	↑ Factor level 15-20%
Cryoprecipitate	1-2 units/kg	↑ Fibrinogen by 60-100 mg/dL

Common initial doses of blood components and expected effects in children

Massive Transfusion in Pediatrics – Defined

Chidester et al. *A Pediatric Massive Transfusion Protocol*. J Trauma Acute Care Surg. 2012

- Massive transfusion - PRBC usage approached 80ml/kg/24 h or 40ml/kg/12 h

Hendrickson et al. *Implementation of a pediatric trauma massive transfusion protocol: one institution's experience*. Transfusion 2012

- Massive transfusion – requirement of 1 blood volume of products (70ml/kg)

Neff et al. *Clearly defining pediatric massive transfusion: Cutting through the fog and friction with combat data* J Trauma Acute Care Surg. 2015

- Massive Transfusion – 40 ml/kg of any blood product in 24 hrs

Massive transfusion in children & neonates

Yaser A. Diab, et al. British Journal of Haematology, 2013

Defining massive transfusion in children has not been clearly established

Adult definitions are not applicable in pediatrics as TBV varies according to age and weight

Authors suggest defining peds MT as:

- Transfusing > 50% TBV in 3 hr
- Transfusion > 100% TBV in 24 hr
- Transfusion support to replace ongoing blood loss of >10% TBV/min

*TBV varies according to age and weight

*MT definitions must be relative to TBV in each individual patient

Age Group	Estimated blood volume (ml/kg)
Preterm infant	90-100
Term infant	80-90
Child <3 months	70
Older child	65
Male adult	65
Female adult	60

Clearly defining pediatric massive transfusion: Cutting through the fog and friction with combat data

Lucas P. Neff, MD et al. J Trauma Acute Care Surg. 2015

- Using the largest existing registry of transfused pediatric trauma patients, authors sought a data-driven MT threshold
- Over 12 year period, 1,113 out of 4,990 combat-injured pediatric trauma patients were transfused
- Using their MT definition of 40ml/kg mortality and morbidity were examined between MT+ and MT- groups
 - MT+ group: greater shock, coagulopathy, thrombocytopenia, higher ISS, more mechanical ventilator days, longer ICU stay and overall higher mortality
- Concluded – threshold of 40ml/kg of all blood products given in the first 24 hours reliably identifies critically injured children at high risk for early and in-hospital death
- This evidence-based definition will provide a consistent framework for future research and protocol development in pediatric resuscitation

Massive Transfusion: Protocols and Transfusion Ratios & Lab Monitoring

- Pediatric data is limited
 - Little published on trauma induced coagulopathy, what defines MT, and use of MTP's
- Most knowledge comes from adult studies or pediatric case series, case reports, small retrospective studies and single center experience
 - Unclear adult data can be generalized to pediatric patients
- Many suggest application of MTP's in peds trauma, protocol development has been challenging
- We first need to understand the impact of administering components as ratios before developing evidence based protocol
- Optimal strategy for selection of volumes and types of components to use and for clinical and lab monitoring in peds patient requiring MT remains unclear

Hendrickson et al. Implementation of a pediatric trauma massive transfusion protocol: one institution's experience. Transfusion 2012

- Retrospective study
 - 53 patients in MTP vs 49 pre MTP
- In the MTP group
 - No improvement in mortality
 - Median time to FFP transfusion decreased x4
 - FFP:RBC transfusion ratio increased 2x

A MTP with fixed ratios is feasible for pediatric trauma... Implementation has increased RBC:FFP ratios and obtained FFP faster in coagulopathic children. More studies needed to assess outcome!

Although the authors identified multiple limitations to their study, they hope that "the protocol driven description will help to guide other members of the pediatric trauma community who are trying to optimize blood product resuscitation for their patients."

Neonate (1-5 kg)					Infant (6-10 kg)				
Package	RBC	Plasma	PLTs	Cryo	Package	RBC	Plasma	PLTs	Cryo
1	½ unit	½ unit			1	1 unit	1 unit		
2	½ unit	½ unit	½ apheresis		2	1 unit	1 unit	½ apheresis	
3	½ unit	½ unit		1 unit	3	1 unit	1 unit		2 units
4	½ unit	½ unit	½ apheresis		4	1 unit	1 unit	½ apheresis	
5	½ unit	½ unit		1 unit	5	1 unit	1 unit		2 units

Younger child (11-25 kg)					Older child (26-50 kg)				
Package	RBC	Plasma	PLTs	Cryo	Package	RBC	Plasma	PLTs	Cryo
1	2 units	2 units			1	3 units	3 units		
2	2 units	2 units	1 apheresis		2	3 units	3 units	1 apheresis	
3	2 units	2 units		4 units	3	3 units	3 units		6 units
4	2 units	2 units	1 apheresis		4	3 units	3 units	1 apheresis	
5	2 units	2 units		4 units	5	3 units	3 units		6 units

Adolescent (>50 kg)				
Package	RBC	Plasma	PLTs	Cryo
1	5 units	5 units		
2	5 units	5 units	1 apheresis	
3	5 units	5 units		8 units
4	5 units	5 units	1 apheresis	
5	5 units	5 units		8 units

Example of weight based pediatric Massive Transfusion Protocol

Fixed ratios of RBC's:FFP: platelets: cryoprecipitate based on weight

Hendrickson et al. Implementation of a pediatric trauma massive transfusion protocol. Transfusion 2012

There are limitations to the study, but this is the first study describing rTEG in pediatric trauma. Authors believe that... "the true benefit of rTEG may be its POC availability and the ability to receive rapid, reliable, actionable data in the trauma bay... enabling.. rapid assessment of coagulopathy in clinical management. A protocol-driven prospective trial of goal-directed hemostatic resuscitation algorithms using rTEG parameters is a natural extension of this concept that has the potential to improve the resuscitation of severely injured children."

Vogel et al. Admission rapid thrombelastography delivers real-time "actionable" data in pediatric trauma. J Ped Surg 2013

Measures of coagulation

INR, PT, PTT vs. Thromboelastography (TEG)

- CCT's designed for screening of heritable bleeding disorders 2* factor deficiencies
- Monitor therapeutic anticoagulants
- Conventional coagulation tests of blood coagulation are static
 - Poor test for dynamic assessment of clot strength in whole blood
- Measure platelet poor component of blood – discount interaction of whole blood with platelets and fibrinogen
 - Essential for monitoring patients with post-injury coagulopathy
- Is TEG a better way to monitor coagulopathic trauma patients?
- TEG guided/goal directed resuscitation has taken off in the adult trauma literature
 - VERY LITTLE published in the pediatric trauma population

Blood Product Ratios in Pediatric Trauma

- Adult literature has taken off in the last 8-10 years
- Multiple retrospective studies in adult trauma suggest 1:1 FFP:PRBC's & ≥ 1:2 PLT:PRBC's
- There is little to no specific published data to guide transfusion ratios in peds trauma
- Is it appropriate to extrapolate to pediatric trauma?
 - Data obtained from penetrating trauma in health young adult males

Admission rapid thrombelastography delivers real-time "actionable" data in pediatric trauma

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Key words: Pediatric trauma; Thromboelastography; TEG; Goal-directed hemostatic resuscitation

Abstract Purpose: Admission rapid thrombelastography (rTEG) is a "real-time" clinical tool used to evaluate trauma-induced coagulopathy and direct hemostatic resuscitation. The relationship of rTEG to conventional coagulation tests (CCT) and early lifesaving interventions (LSI) in pediatric trauma is unknown. Methods: Severely injured patients (age ≤ 14 years) with an rTEG were retrospectively reviewed (8/1/2009–8/31/2011). Demographic and clinical information was collected. Spearman's correlation and regression models were used to evaluate rTEG with respect to CCT, early transfusion, LSI, and mortality. Results: Eighty-six patients were identified. The median age was 8 years, and the median injury severity score (ISS) was 21. Activated clotting time (r = 0.66), R-time (r = 0.77), and α-angle (r = -0.73) showed

r-TEG use in pediatric trauma

- *Retrospective review of severely injured pediatric trauma patients
- *r-TEG was evaluated with respect to CCT's, early transfusion, LSI & mortality
- *Results showed good correlation with CCT's, and predictive of early transfusion, early LSI and mortality
- *PROVIDES VALUABLE DATA FOR GOAL-DIRECTED HEMOSTATIC RESUSCITATION IN PEDIATRIC TRAUMA

Journal of Pediatric Surgery

The impact of blood product ratios in massively transfused pediatric trauma patients

Lauren Nosanov, B.A.^a, Kenji Inaba, M.D.^{a,*}, Obi Okoye, M.D.^a, Shelby Resnick Jeffrey Upperman, M.D.^b, Ira Shulman, M.D.^c, Peter Rhee, M.D., M.P.H.^d, Demetrios Demetriades, M.D., Ph.D.^e

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The American Journal of Surgery (2013) 206, 655-660

KEYWORDS: Pediatric Trauma

Abstract BACKGROUND: Few studies have examined the impact of balanced resuscitation in pediatric trauma patients requiring massive transfusions. Adult data may not be generalizable to children.

- *Retrospective analysis of pediatric trauma patients who received massive transfusion
- *No specific MTP followed
- *Transfusion was dictated by individual providers discretion
- *Compared plasma:PRBC and platelet:PRBC ratios to mortality

Nosanov et al. *The impact of blood product ratios in massively transfused pediatric trauma patients.* Am J of Surgery 2013

- Higher ratios were not associated with increased survival
- They did find that all deaths were caused by severe head injury
- Because of the retrospective nature, small numbers and lack of death due to hemorrhage, it is difficult to draw absolute conclusions from this study
- Currently still unclear what constitutes massive transfusion in pediatrics, when a MTP should be instituted and what product ratios are best

Additional prospective studies are needed!

WTA 2014 PLENARY PAPER

J Trauma Acute Care Surg 2014

Tranexamic acid administration to pediatric trauma patients in a combat setting: The pediatric trauma and tranexamic acid study (PED-TRAX)

Matthew J. Eckert, MD, Thomas M. Wertin, MD, Stuart D. Tyner, PhD, Daniel W. Nelson, DO, Seth Izenberg, MD, and Matthew J. Martin, MD, Tacoma, Washington

BACKGROUND: Early administration of tranexamic acid (TXA) has been associated with a reduction in mortality and blood product requirements in severely injured adults. It has also shown significantly reduced blood loss and transfusion requirements in major elective pediatric surgery, but no published data have examined the use of TXA in pediatric trauma.

METHODS: This is a retrospective review of all pediatric trauma admissions to the North Atlantic Treaty Organization Role 3 hospital, Camp Bastion, Afghanistan, from 2009 to 2012. Univariate and logistic regression analyses of all patients and select subgroups were performed to identify factors associated with TXA use and mortality. Standard adult dosing of TXA was used in all patients.

RESULTS: There were 766 injured patients 18 years or younger (mean [SD] age, 11 [5] years, 88% male, 73% penetrating injury, mean

- *Retrospective review of pediatric trauma admissions over 4 yr period
- *TXA use and mortality were analyzed
- *TXA was at discretion of physician, adult dosing regimen used
- *TXA use was independently associated with decreased mortality among all patients,
 - no increase in thromboembolic or cardiovascular adverse events and
 - suggested improved discharge neuro status and decreased vent dependence

RCPCH
Royal College of Paediatrics and Child Health
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Evidence Statement
Major trauma and the use of tranexamic acid in children
November 2012

Key points

- Tranexamic acid reduces mortality in adult trauma
- Early administration is vital for efficacy
- Due to the lack of published data on the use of tranexamic acid in paediatric patients who have undergone major trauma there is no evidence for a specific dose in this situation
- The RCPCH and NPPG Medicines Committee recommend a pragmatic dosage schedule – 15mg/kg tranexamic acid loading dose (max 1g) over 10 minutes followed by 2mg/kg per hour

← CRASH-2 trial 2010

Dosing schedule based on CRASH-2 data (1gm LD and 1g over 8hours) but translated to children. Administration within the first 3 hrs of injury is likely beneficial.

Recombinant Activated Factor VIIa

- Only FDA approved for hemophilia patients with factor inhibitors
- The majority of its use has been "off label" – i.e. hemorrhage in trauma
- Induces hemostasis at the site of vascular injury independent of FVIII and FIX by complexing with exposed tissue factor
- Although there have been a small handful of pediatric trauma case reports of its use, there are no prospective studies showing safety and efficacy
- Side effects: EXPENSIVE, risk of thromboembolus, short half life (2.7h)
- If used – ensure repletion of coagulation factors, correction of acidosis and hypothermia

Beno et al. *Tranexamic acid in pediatric trauma: why not?* Critical Care 2014

- Authors argue "for" strong consideration of TXA in appropriate peds trauma victims
- Trauma induced coagulopathy has been documented in severely injured pediatric patients and has been associated with increased mortality
- Many published doses documented in non-trauma peds literature (10-100mg/kg LD): cardiac, spinal, craniofacial – adverse events are rare
- The emerging concern of post administration seizures has not been reported for the dose used in trauma

"Denying injured children TXA due to the lack of pediatric trauma trial evidence in this indication is likely shortsighted and unnecessary given the ample clinical evidence in other pediatric settings, the excellent safety record of the drug, and the clear mortality benefit seen in adult trauma."