PEDIATRIC MASSIVE TRANSFUSION

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CROZER-CHESTER MEDICAL CENTER/VILLANOVA UNIVERSITY NURSE ANESTHESIA PROGRAM
LEADING CAUSE OF DEATH

• Trauma
  • Motor vehicle accidents, nonaccidental trauma, homicide, and suicide are the leading causes of death in children 1-21 years old
  • Hemorrhage remains the leading cause of preventable traumatic death [nearly half]

• 7.1% transfusion rate in the pediatric patients
  • 16.6% overall transfusion rate for trauma
AT-RISK GROUP: NEONATES

- Hemostatic system is incompletely developed at birth
- The concentration of procoagulant and anticoagulant proteins is low and remains so until 6 months of age
- Fibrinogen is qualitatively dysfunctional, existing in fetal form for 6–12 months after birth

= Increased bleeding risk
ASSESSMENT OF BLOOD LOSS

• Principles of assessing pediatric massive blood loss are similar to adults

• Children have a good physiological reserve
  • Capable of maintaining a near normal blood pressure even after the loss of 30-40% blood volume
  • May not be able to rely on vital signs
<table>
<thead>
<tr>
<th>Gauze Size</th>
<th>Percentage of Saturation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25%</td>
</tr>
<tr>
<td></td>
<td>50%</td>
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<tr>
<td></td>
<td>50%</td>
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<tr>
<td></td>
<td>100%</td>
</tr>
<tr>
<td>10×10 cm</td>
<td>3 mL</td>
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<tr>
<td></td>
<td>6 ml</td>
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<tr>
<td></td>
<td>6 ml</td>
</tr>
<tr>
<td></td>
<td>12 mL</td>
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<tr>
<td>30×30 cm</td>
<td>25 mL</td>
</tr>
<tr>
<td></td>
<td>50 mL</td>
</tr>
<tr>
<td></td>
<td>75 mL</td>
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<tr>
<td></td>
<td>100 mL</td>
</tr>
<tr>
<td>45×45 cm</td>
<td>40 mL</td>
</tr>
<tr>
<td></td>
<td>80 mL</td>
</tr>
<tr>
<td></td>
<td>120 mL</td>
</tr>
<tr>
<td></td>
<td>160 mL</td>
</tr>
</tbody>
</table>
place items in bucket to begin weighing

QBL
1083
ml

v-shape
350
ml

weighed items
733
ml

Hb Loss
5.73 g
Eight years of experience with massive blood transfusions.

Authors: Wilson RF, Mammen E, Walt AJ


Publication Type: Journal Article

Language: English

Journal Info: Publisher: Lippincott Williams & Wilkins Country of Publication: United States NLM ID: 0376373 Publication Model: Print Cited Medium: Print ISSN: 0022-5282 (Print) Linking ISSN: 00225282 NLM ISO Abbreviation: J Trauma Subsets: Core Clinical (AIM); MEDLINE

Imprint Name(s): Publication: 1998- : Baltimore, MD : Lippincott Williams & Wilkins
Original Publication: Baltimore, Williams & Wilkins.

MeSH Terms: Blood Transfusion*
Hemorrhage/*therapy
Abdominal Injuries/mortality; Adolescent; Adult; Age Factors; Aneurysm/complications; Aneurysm/surgery; Blood Coagulation Disorders/complications; Blood Group Incompatibility; Blood Platelet Disorders/complications; Child; Coombs Test; Factor V Deficiency/complications; Factor VIII; Fibrinogen; Gastrointestinal Hemorrhage/therapy; Hemorrhage/complications; Hemorrhage/etiology; Hemorrhage/mortality; Homeostasis; Humans; Infection/complications; Cirrhosis/complications; Middle Aged; Neoplasms/complications; Pancreatitis/complications; Prothrombin Time; Retrospective Studies; Rupture/complications; Shock/complications; Vascular Diseases/surgery; Wounds and Injuries/complications; Wounds and Injuries/mortality

Substance 9001-27-8 (Factor VIII)
Nomenclature: 9001-32-5 (Fibrinogen)
Early resuscitation intensity as a surrogate for bleeding severity and early mortality in the PROMMTT study

Elaheh Rahbar, PhD, Erin E. Fox, PhD, Deborah J. del Junco, PhD, John A. Harvin, MD, John B. Holcomb, MD, Charles E. Wade, PhD, Martin A. Schreiber, MD, Mohammad H. Rahbar, PhD, Eileen M. Bulger, MD, Herb A. Phelan, MD, MSCS, Karen J. Brasel, MD, MPH, Louis H. Alarcon, MD, John G. Myers, MD, Mitchell J. Cohen, MD, Peter Muskat, MD, and Bryan A. Cotton, MD, MPH, on behalf of the PROMMTT Study Group, Houston, Texas
DEFINING MASSIVE TRANSFUSION

• Classically- large volume over given time period
  • Arbitrary volumes
• Little relevance in Pediatrics
• Assessment of blood consumption (ABC)
Stahworth, S., et al. Reappraising the concept of massive transfusion in trauma. Critical Care. 2010; 14

**Figure 1 Transfusion-related mortality.** Mortality by packed red blood cells (PRBCs) administered during the first 24 hours of admission.
Neff, L. et al., Clearly defining pediatric massive transfusion: Cutting through the fog and friction with combat data. *J Trauma Acute Care Surg.* 2014; 78(22)
Rahbar, E. Early resuscitation intensity as a surrogate for bleeding severity and early mortality in the PROMMTT study. *J Trauma Acute Care Surg.* 2013; 74(7)
MASSIVE TRANSFUSION PROTOCOL PLANNED EMERGENCY*

• Adults - clinical triggers
• Pediatrics - proven unreliable because no validated MT prediction models exist
• No clear triggers for MT protocol activation
• Clear survival benefit in pediatric trauma receiving MT via MTP is NOT documented
1. Cryoprecipitate at a volume of 4 mL/kg may be administered after administration of all three components (after estimated loss of two blood volumes) or if fibrinogen levels fall below 1-1.5 g/L.

2. Consider off-label use of recombinant factor VIII (rFVIIIa), 90 µg/kg, if ongoing bleeding persists after loss of 3 blood volumes.

For patients who weigh more than 30 kg, a 1:1:1 algorithm should be followed. Transfuse blood component volumes of 1 unit of PRBCs to 1 unit of FFP to 1 unit of pooled platelets, as in adult protocols (see text).

*BV = estimated Blood Volume (generally 70-90 mL/kg based on weight of child as shown in Table 1)*

Massive transfusion protocol for pediatric trauma (estimated weight less than 30 kg)

Figure appears in Dehmer JJ, Adamson WT. Massive transfusion and blood product use in the pediatric trauma patient. Seminars in Pediatric Surgery (2010) 19, 286-291.
Pathophysiological factors contributing to coagulopathy during massive transfusion. Diab and colleagues, British Journal of Haematology.
TRANSFUSION INDUCED COAGULOPATHY

• Coagulopathy may also develop during massive transfusion
  • Hemodilution from volume replacement
  • Exacerbated by hypothermia and acidosis
    • Storage temperature of blood products at 1–6°C
    • 1°C decrease in temperature, coagulation factor activity decreases 10%. Below 34°C, clotting times prolong, platelets pool within the spleen, and there is impaired adherence and aggregation

• Significant hypocalcaemia
  • Induced by blood product citrate binding to circulating serum calcium and acidosis (pH<7.3)
  • Reduces the activation of coagulation on platelet cell surfaces and disrupts hemostasis
DOES TRANEXAMIC ACID HAVE A ROLE?

• Research demonstrates reduction in mortality with the early use of TXA in adult trauma patients

• TXA used perioperatively reduces transfusion requirements in children

• Trauma patients are susceptible to hyperfibrinolysis

<table>
<thead>
<tr>
<th>Table 2 Tranexamic acid dosing in pediatric trauma</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
</tr>
<tr>
<td>≥12 years:adult protocol</td>
</tr>
<tr>
<td>&lt;12 years</td>
</tr>
</tbody>
</table>

The Hospital for Sick Children Massive Hemorrhage Protocol for the use of tranexamic acid in pediatric trauma. April 2014. Adapted from Royal College of Paediatrics and Child Health: Evidence statement - Major trauma and the use of tranexamic acid in children [39].
BALANCED RESUSCITATION

• Coagulopathy is present in approximately 65% of patients requiring MT
  • Aim to avoid or treat acute traumatic coagulopathy and to prevent deaths from hemorrhage
• Target plasma/PRBC/platelet ratio approaching 1:1:1
PRBC STORAGE

• Stored up to 42 days
  • Day 14: 2,3 DPG-decreases to almost undetectable levels
  • Day 35: pH gradually becomes acidic (6.6-6.8)

• Red cells lose K+ and gain Na+ during storage
  • Affected by storage solution

• Should there be age-guided dispensing?
METABOLIC ABNORMALITIES WITH RAPID TRANSFUSION

• Citrate toxicity
  • Hypocalcemia
  • Hypomagnesemia
    • Magnesium chloride rather than with magnesium sulphate -sulphate ions can bind to calcium and worsen the condition

• Acidosis

• Hypothermia

• Hypo and Hyperkalemia
UNPLANNED EMERGENCY: TAHCA

• Transfusion-associated hyperkalemic cardiac arrest
  • Rate of transfusion, irradiation, and type of additive used

• Acidosis, hyperglycemia, hypocalcemia, and hypothermia at the time of arrest
  • Factors which may depress cardiac output
WAKE UP SAFE®

The Pediatric Anesthesia Quality Improvement Initiative

January 27, 2015

Over the past 4 years, seven cases of hyperkalemia-associated cardiac arrest or near-cardiac arrest during massive transfusion have been reported to Wake Up Safe. Of these, three patients had documented hyperkalemia and four were suspected of having hyperkalemia. The case profiles submitted were as follows: an infant undergoing myelomeningocele repair; an infant undergoing resection of an abdominal tumor; a premature neonate undergoing resection of sacrococcygeal teratoma; an infant undergoing sagittal synostectomy for craniosynostosis; a neonate undergoing resection of a facial mass; a child undergoing cardiac surgery with cardiopulmonary bypass support; and a teenager in extremis undergoing emergency laparotomy for free air. In two of these patients, the serum potassium levels exceeded 8 mmol/L during transfusion of red blood cell (RBC) units that were 21 and 28 days old in one patient, and 23 days old in the other. In the third case, serum potassium level exceeded 6 mmol/L after transfusion of RBC units that were 5 days old. In the other
Hyperkalaemia during rapid blood transfusion and hypovolaemic cardiac arrest in children

Karen A. Brown MD FRCP, Bruno Bissonnette MD FRCP, Brian McIntyre MD FRCP

A morbidity and mortality review documented a high occurrence of hyperkalaemia in cardiac arrests associated with rapid blood transfusion, which resulted in further study. In order to simulate events during rapid blood transfusion and cardiac arrest, the central circulation was modeled as a linear one compartment, and used to simulate a child who suffered a hypovolaemic cardiac arrest and was resuscitated with rapid blood transfusion (RBT). The simulation suggested that the combination of RBT and a low cardiac output state could be associated with hyperkalaemia. If the potassium concentration in the plasma fraction of the transfused blood was ≥10 mmol·L⁻¹, then the use of TSR combined with a low cardiac output state could be associated with hyperkalaemia. Nous avons alors colligé rétrospectivement la kaliémie mesurée lors de 138 cas d'arrêt cardiaque chez des enfants, pour s'apercevoir qu'elle s'élevait à 8.23 ± 1.99 mmol·L⁻¹ chez ceux qui avaient reçu des TSR durant la réanimation alors qu'elle n'était que de 5.63 ± 2.39 chez les autres (P < 0.05). Les TSR employées chez ces enfants hypovolémiques au faible débit cardiaque ont pu contribuer à l'hyperkaliémie observée lors de l'arrêt cardiaque.

A morbidity and mortality review of cardiac arrests at our institution showed that a number of intraoperative cardiac arrests was associated with hyperkalaemia. Cardiac arrest was defined as severe hypotension which required the institution of CPR. This was unexpected because hyperkalaemia during cardiac arrest is unusual. The common denominator is the cardiac arrests associated with hyperk...
ASA PRACTICE ADVISORY

• In asymptomatic or nonselected patients, abnormal potassium concentrations were reported in 0.2% to 16%

• Selected high-risk patients, abnormal potassium concentrations were reported in 2.9% to 71%
MEASURES TO REDUCE TAHCA

• Fresher blood, RBC washing, RBC irradiation
  • Preferably within 6 hr of irradiation

• Rate of transfusion
  • Infusion rate at 0.5 mL/kg/min

• Avoidance of rapid infusers in higher-risk patients
  • PIV vs CVC

### TABLE 3. Measures to reduce TAHCA

- Anticipate and replace blood loss before significant hemodynamic compromise occurs.
- Use larger bore (>23 gauge) peripheral IV catheters preferentially over central venous lines for MT.
- Avoid the use of rapid infusers.
- Check and treat electrolyte abnormalities frequently.
- Use “fresh” RBCs for MT, particularly in infants.
- Reduce the plasma volume of RBC units.
- Minimize the interval between irradiation and transfusion.
- Consider washing RBCs or reducing AS if indicated.

MT = massive transfusion.
<table>
<thead>
<tr>
<th>I.V. catheter</th>
<th>Maximum rate of flow with gravity (ml min⁻¹)</th>
<th>Maximum rate of flow with pressure (ml min⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>14 G 50 mm cannula</td>
<td>236.1</td>
<td>384.2</td>
</tr>
<tr>
<td>16 G 50 mm cannula</td>
<td>154.7</td>
<td>334.4</td>
</tr>
<tr>
<td>18 G 45 mm cannula</td>
<td>98.1</td>
<td>153.1</td>
</tr>
<tr>
<td>20 G 33 mm cannula</td>
<td>64.4</td>
<td>105.1</td>
</tr>
<tr>
<td>22 G 25 mm cannula</td>
<td>35.7</td>
<td>71.4</td>
</tr>
<tr>
<td>15 G 25 mm intraosseous needle (tibial)</td>
<td>68.2</td>
<td>204.6</td>
</tr>
</tbody>
</table>
Thank you!!