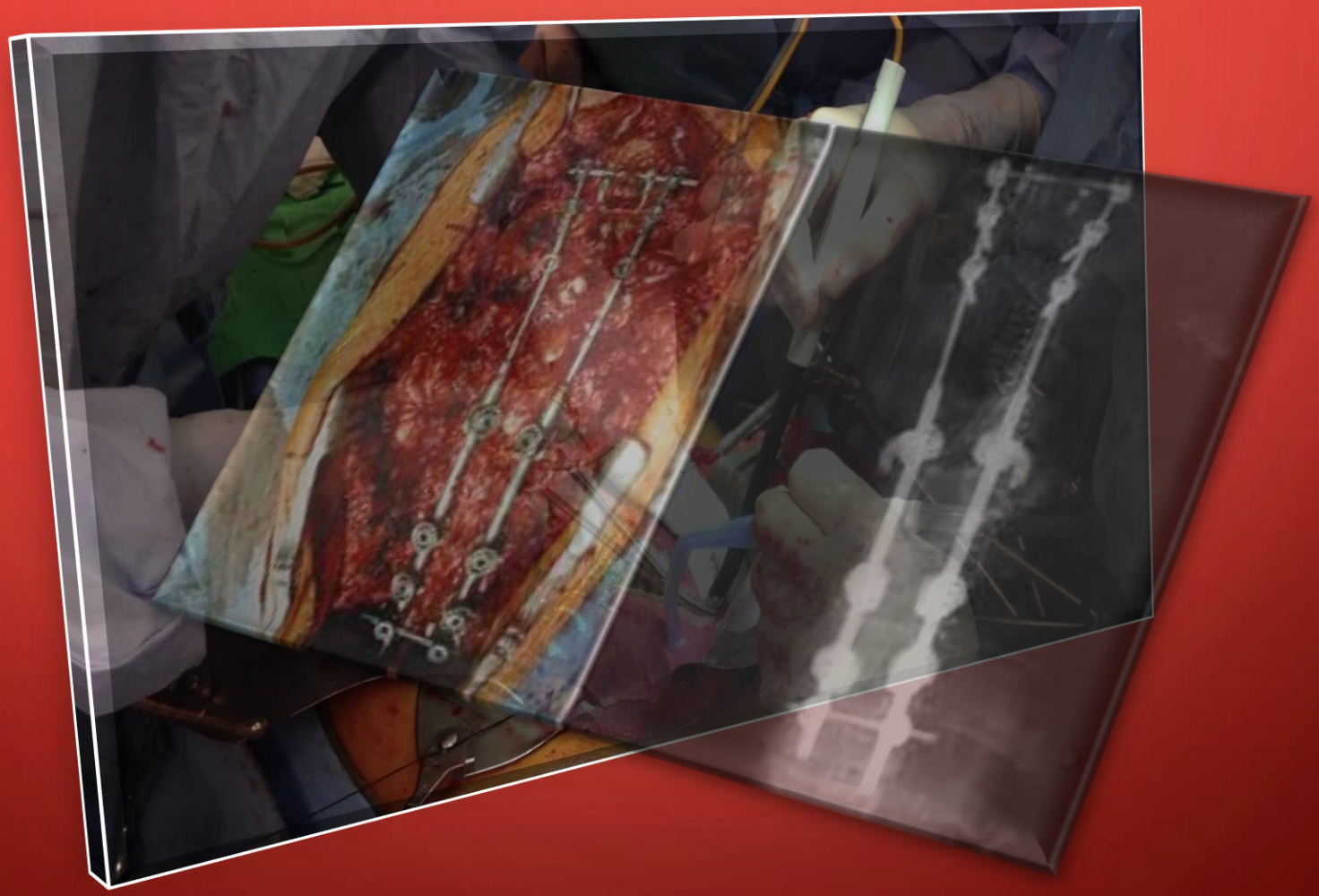
PEDIATRIC MASSIVE TRANSFUSION

CHELSEA RUNKLE RN, BSN, CCRN, SRNA

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

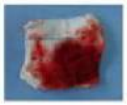
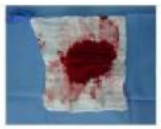
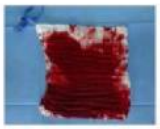
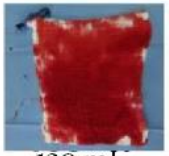
AT-RISK GROUP: NEONATES

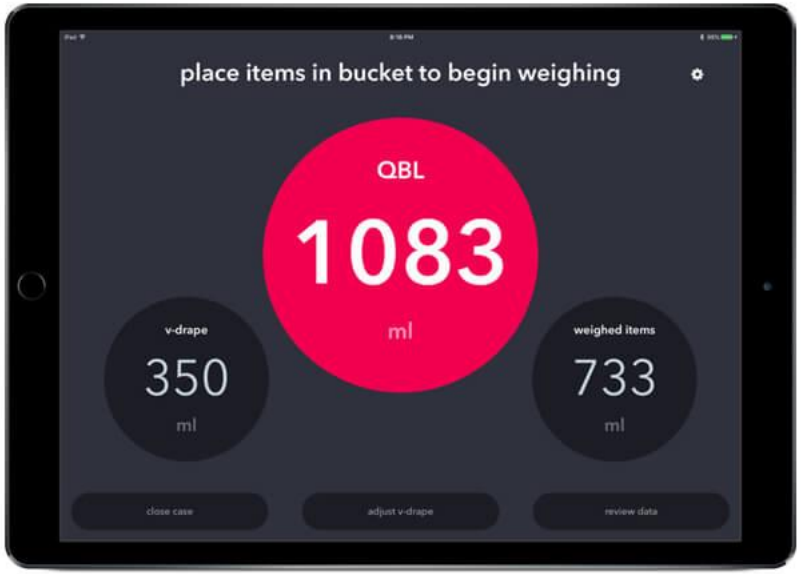
- Hemostatic system is incompletely developed at birth
- The concentration of procoagulant and anticoagulant proteins is low and remains so until 6 months of age
- Fibrinogen is qualitatively dysfunctional, existing in fetal form for 6–12 months after birth

= Increased bleeding risk

ASSESSMENT OF BLOOD LOSS

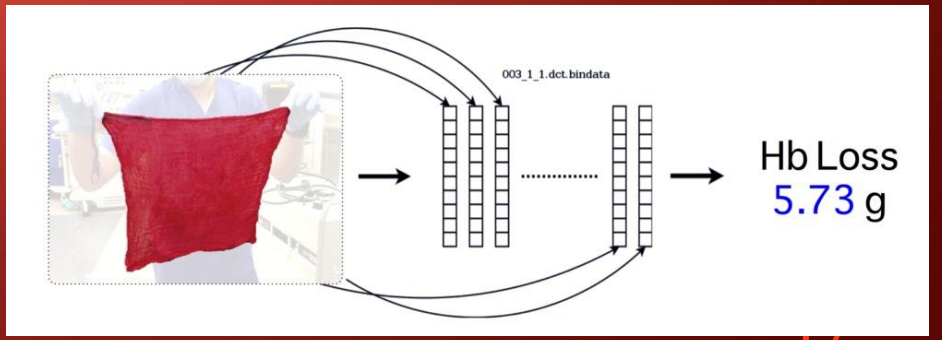
- Principles of assessing pediatric massive blood loss are similar to adults
- Children have a good physiological reserve
  - Capable of maintaining a near normal blood pressure even after the loss of 30-40% blood volume
  - May not be able to rely on vital signs

Gauze Size	Percentage of Saturation			
	25%	50%	50%	100%
10×10 cm	 3 mL	 6 mL	 6 mL	 12 mL
30×30 cm	 25 mL	 50 mL	 75 mL	 100 mL
45×45 cm	 40 mL	 80 mL	 120 mL	 160 mL


place items in bucket to begin weighing
QBL
1083
ml
v-drape
350
ml
weighed items
733
ml
close case
adjust v-drape
review data


349


in out
LAP
27
RT
15
4x4
08
EBL
750


003_1_1.dct.bindata
Hb Loss
5.73 g

Eight years of experience with massive blood transfusions.

Authors: Wilson RF
Mammen E
Walt AJ

Source: The Journal Of Trauma [J Trauma] 1971 Apr; Vol. 11 (4), pp. 275-85.

Publication Type: Journal Article

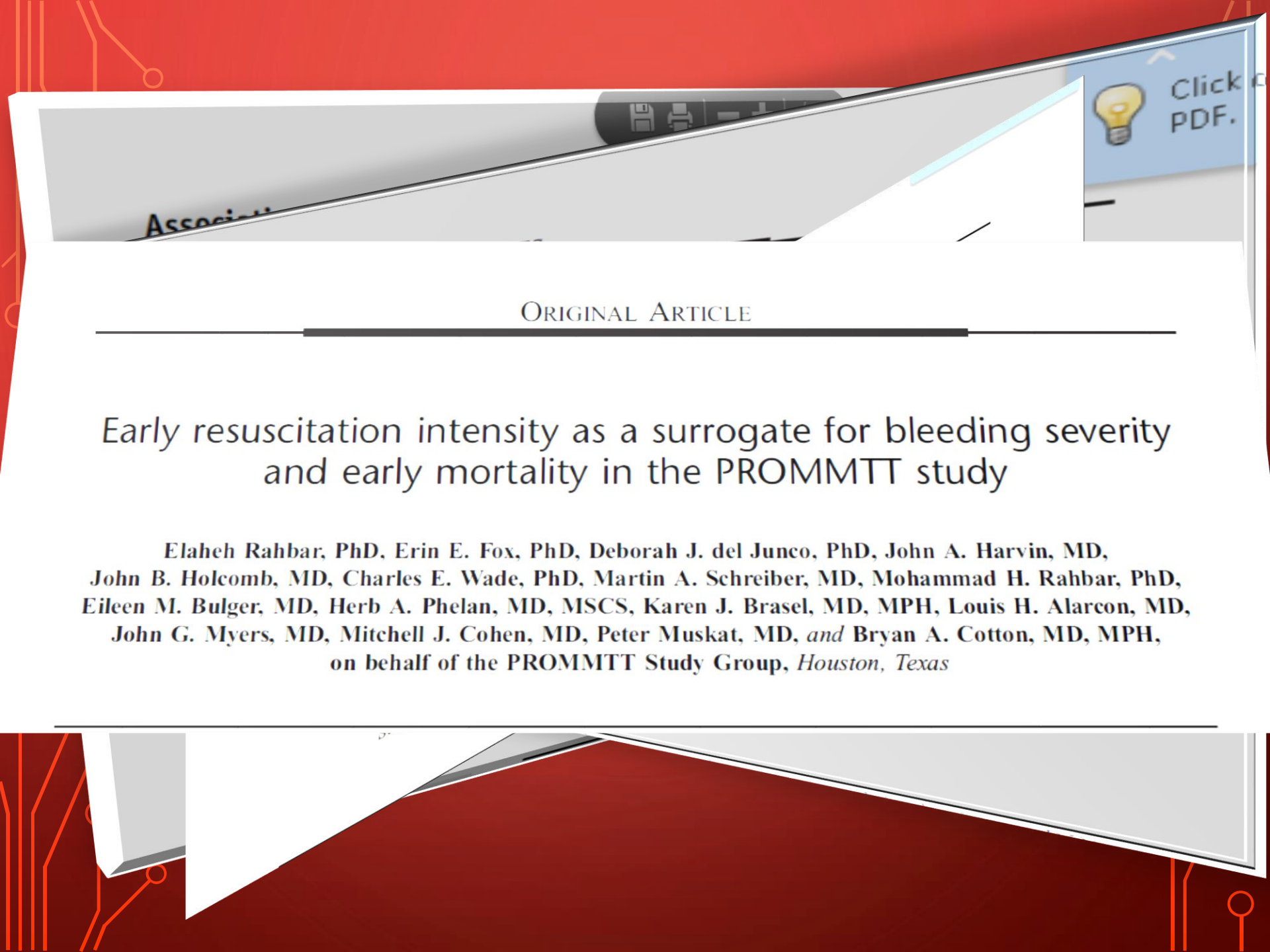
Language: English

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/con 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 Nomenclature: 9001-27-8 (Factor VIII)
9001-32-5 (Fibrinogen)



ORIGINAL ARTICLE

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)

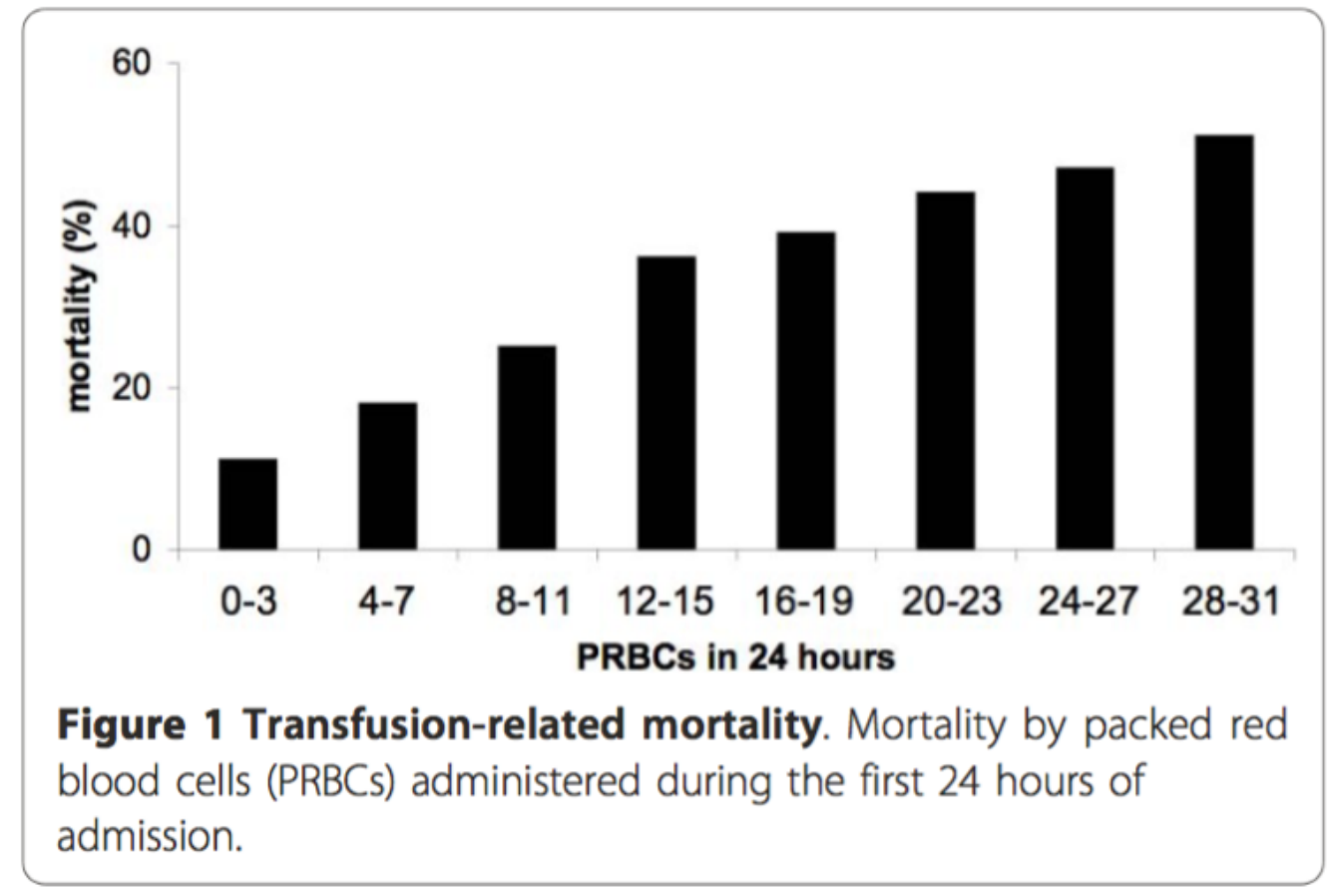
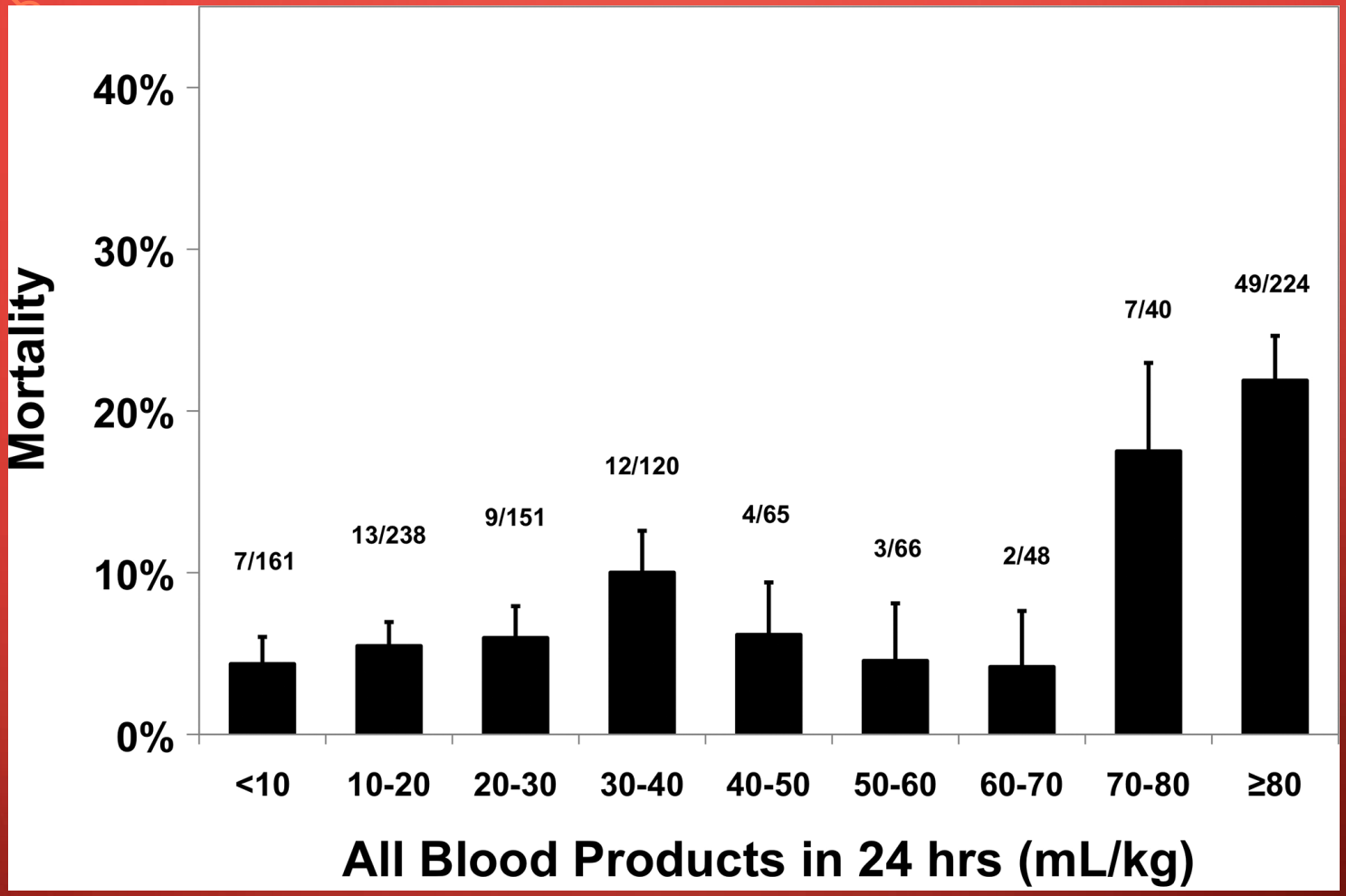
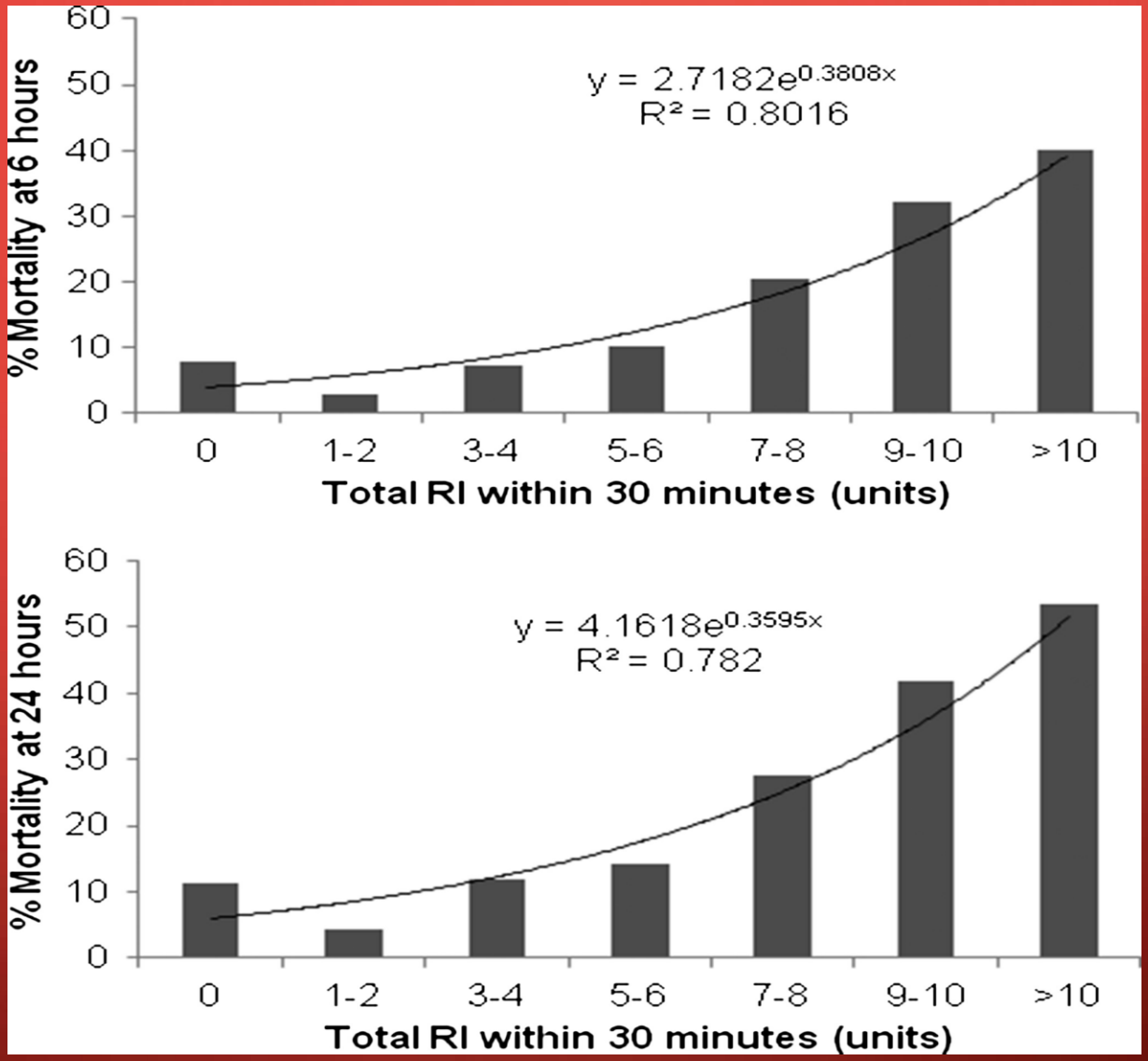


Figure 1 Transfusion-related mortality. Mortality by packed red blood cells (PRBCs) administered during the first 24 hours of admission.

Stanworth, S., et al. Reappraising the concept of massive transfusion in trauma. *Critical Care*. 2010; 14



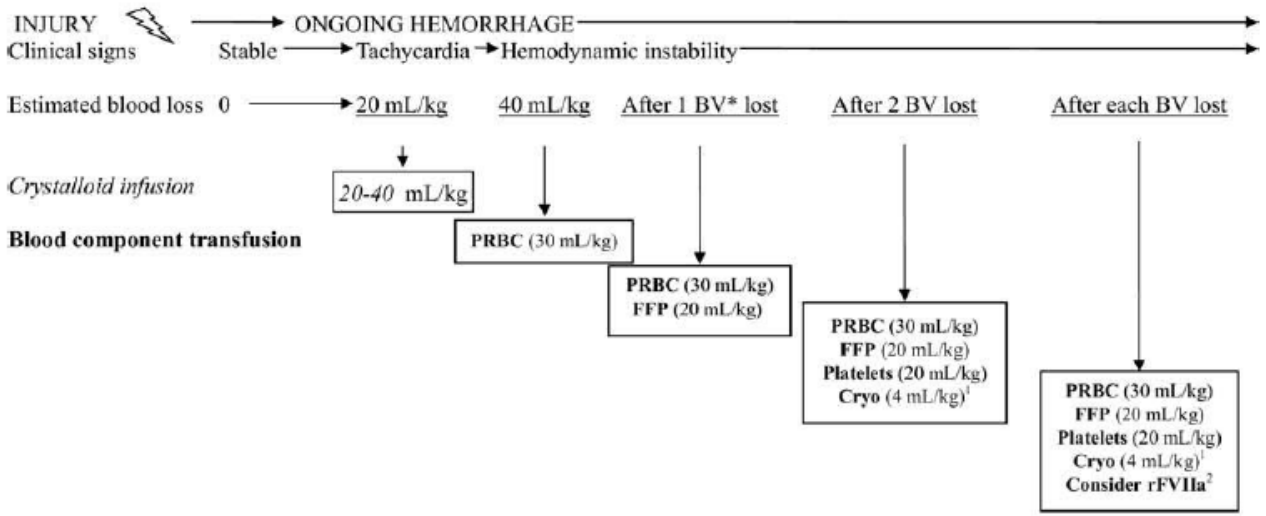
Neff, L. et al., Clearly defining pediatric massive transfusion: Cutting through the fog and friction with combat data. *J Trauma Acute Care Surg.* 2014; 78(22)



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 exists
- 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.

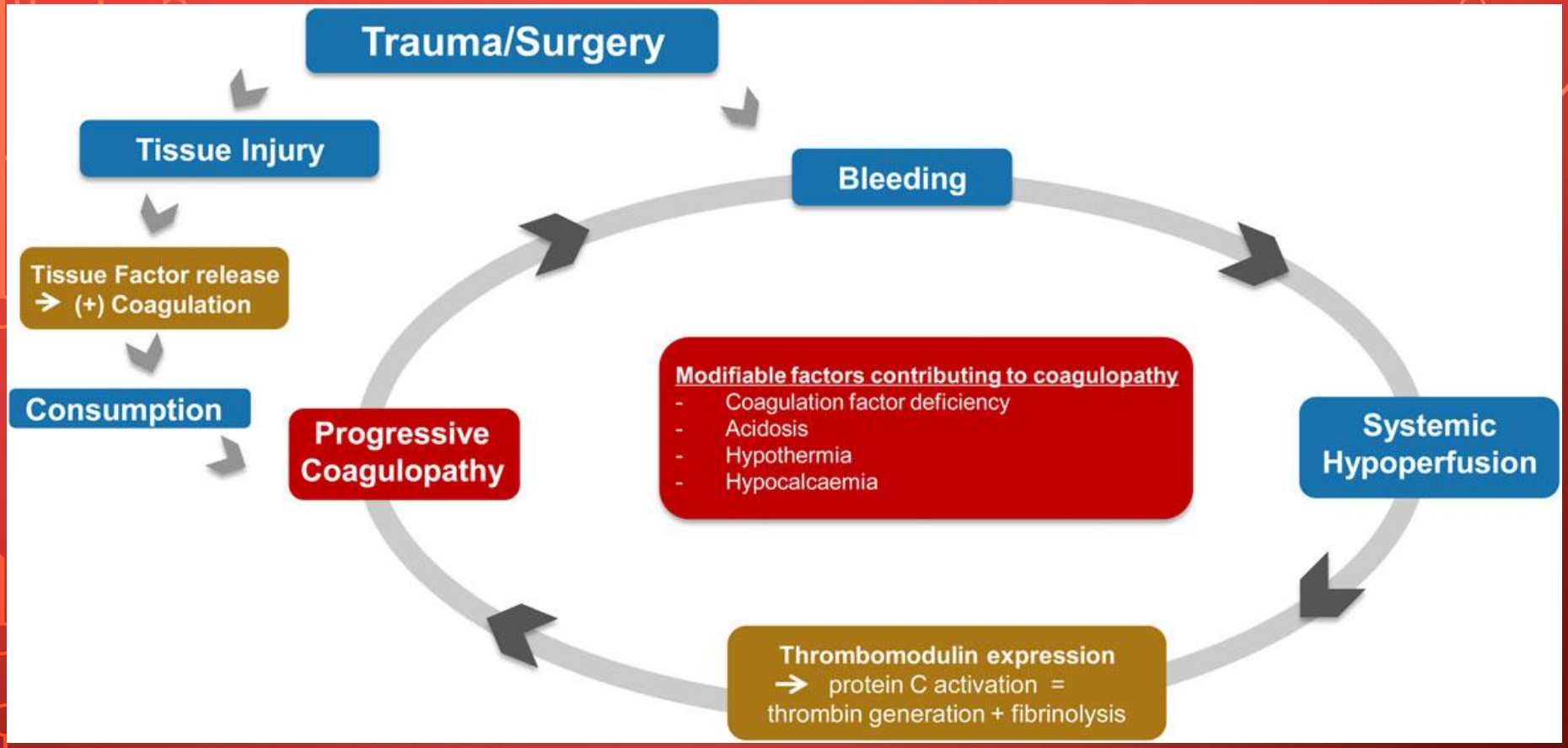
2. Consider off-label use of recombinant factor VIIa **(rFVIIa)**, 90 µg/kg, if ongoing bleeding persists after loss of 3 blood volumes.

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 1unit 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)[2]

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

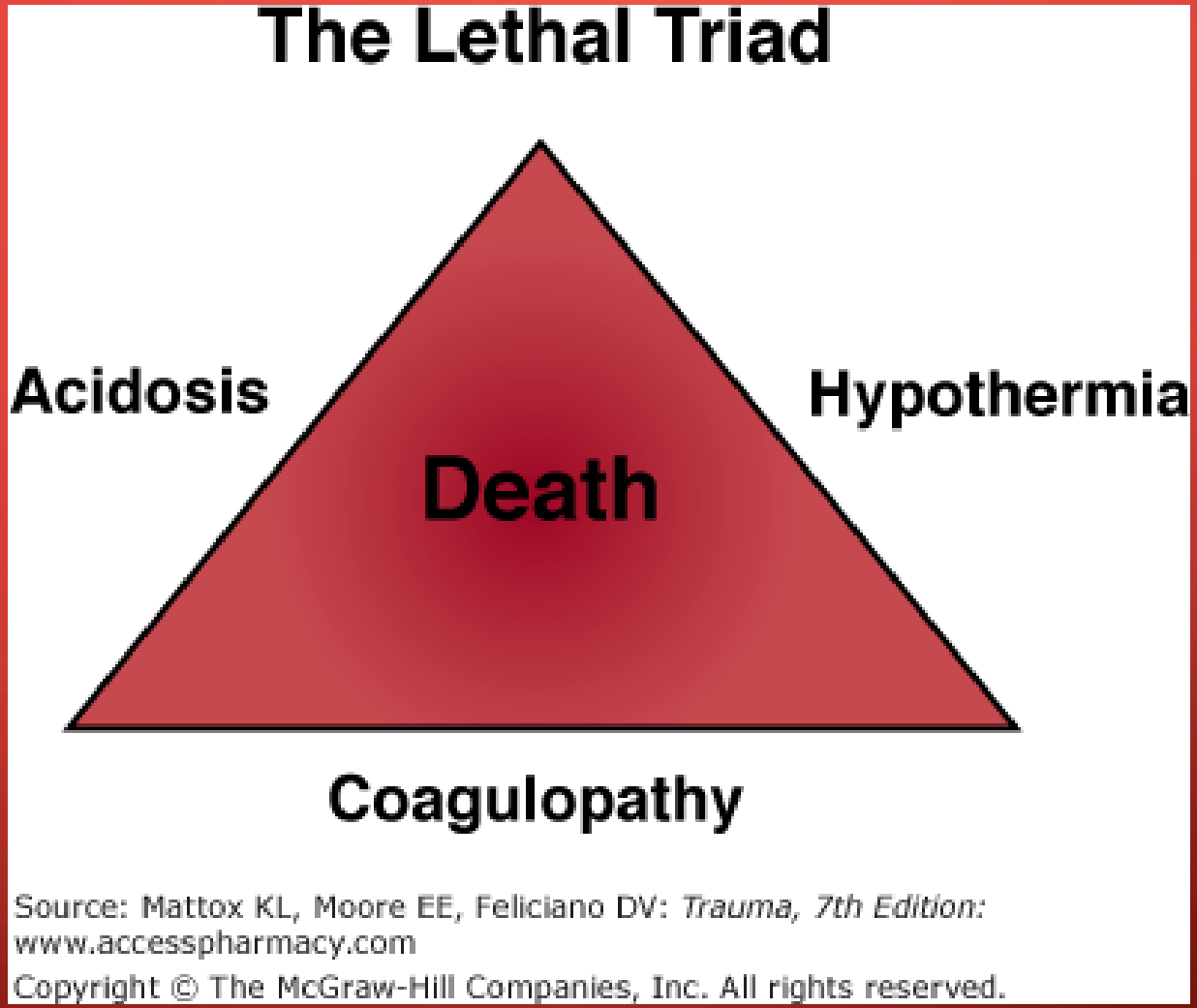
Figure appears in Dehmer JJ, Adamson WT. Massive transfusion and blood product use in the pediatric trauma patient. Seminars in Pediatric Surgery (2010) 19, 286-291.



Pathophysiological factors contributing to coagulopathy during massive transfusion. Diab and collleagues, 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


The Lethal Triad
Acidosis
Hypothermia
Death
Coagulopathy
Source: Mattox KL, Moore EE, Feliciano DV: *Trauma, 7th Edition:*
www.accesspharmacy.com
Copyright © The McGraw-Hill Companies, Inc. All rights reserved.

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 2 Tranexamic acid dosing in pediatric trauma

Age	Loading dose (administer within 3 hours)	Subsequent dose
≥12 years::adult protocol	1 g intravenously over 10 minutes	1 g intravenous infusion over 8 hours
<12 years	15 mg/kg intravenously over 10 minutes (maximum dose 1 g)	2 mg/kg/hr intravenous infusion over 8 hours or until bleeding stops

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 FRCPC, Bruno Bissonnette MD FRCPC, Brian McIntyre MD FRCPC

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}. In an associated clinical study the plasma potassium concentration during cardiac arrest was documented from a retrospective review of 138 cardiac arrests in a paediatric population. Patients were divided into two groups. The RBT-group received a rapid blood transfusion during resuscitation. The non-RBT group did not receive blood during resuscitation. During cardiac arrest the plasma [K] in the non-RBT group was 5.63 ± 2.39 mmol·L^{-1} compared with 8.23 ± 1.99 mmol·L^{-1} in the RBT-group ($P <$

l'aide de TSR. Nous en avons conclu que si la $[K^+]_{plasma}$ du sang transfusé était ≥10 mmol·L^{-1}, l'utilisation de TSR combinée à un faible débit cardiaque pouvait entraîner de l'hyperkaliémie. Nous avons alors colligé rétrospectivement la kaliémie mesurée lors de 138 cas d'arrêt cardiaque chez des enfants, pour s'apercevoir quelle 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 in the cardiac arrests associated with hyper-

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.

Lee, A., et al. Transfusion associated hyperkalemic cardiac arrest in pediatric patients receiving massive transfusion. *Transfusion*. 2014; 54

Table 1 Flow rates of i.v., intraosseous cannulas[6]

I.V. catheter	Maximum rate of flow with gravity (ml min^{-1})	Maximum rate of flow with pressure (ml min^{-1})
14 G 50 mm cannula	236.1	384.2
16 G 50 mm cannula	154.7	334.4
18 G 45 mm cannula	98.1	153.1
20 G 33 mm cannula	64.4	105.1
22 G 25 mm cannula	35.7	71.4
15 G 25 mm intraosseous needle (tibial)	68.2	204.6

Blain, S., et al. Paediatric massive transfusion. *BJA Education*, 2016;16 (8)

Thank you!!