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JUST THE FACTS

Just the facts: damage control resuscitation in pediatric trauma

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Clinical scenario

An 8-year-old male is brought to the emergency department (ED) after being hit by a car while cycling. His primary survey is significant for a Glasgow Coma Scale (GCS) of 12 (E3V4M5) and profound shock (HR 160, BP 85/60, capillary refill 4 s). There is thoracoabdominal wall bruising with normal chest and pelvic radiography, but an extended focused assessment with sonography for trauma (eFAST) is positive for intra-abdominal free fluid. No other bleeding sources are identified.

Which damage control resuscitation principles are used in pediatric patients?

Damage-control resuscitation is a key strategy for children with life-threatening bleeding. The principles for pediatric patients mirror those for adults and include:

1. **Hemorrhage control**—Direct pressure, tourniquet, wound closure (e.g., scalp), pelvic binding.
2. **Limiting crystalloids/colloids**
3. **Early antifibrinolytic therapy**
4. **Prevention or correction of acidosis, hypothermia, hypocalcemia**
5. **Hemostatic resuscitation**—Plasma-to-red blood cell ratio ≥ 1:1 or low-titer group O whole blood

Improving pediatric survival involves early shock recognition, advancing prehospital hemostatic resuscitation, rapid blood product deployment, effective vascular access, optimized massive hemorrhage protocols and minimizing time to definitive hemorrhage control [1]

Hemorrhagic shock presentation: children versus adults?

Hemorrhagic shock in young children presents differently from adults, classically as tachycardia with signs of poor perfusion (delayed capillary refill, cool extremities, and altered mental status) rather than overt hypotension, initially. Children compensate robustly to maintain their stroke volume via increasing heart rate and vasoconstriction; thus, hypotension appears only after significant blood loss (35–45% total blood volume) and represents a decompensated shock state/peri-arrest condition. Recognizing these

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signs early is critical and allows for timely damage control resuscitation [2].

Early recognition of shock, bleeding control, and timely blood transfusion (prehospital if feasible) are critical. Vascular access in volume-depleted children is challenging; intraosseous access is often required, with alternative sites to the proximal tibia including distal femur, proximal humerus (≥5 years), and peripheral veins. Crystalloids should be limited to ≤20 mL/kg if possible, with rapid transition to warmed blood products. Commercial tourniquets and pelvic binders are effective, though improvisation may be needed in children < 5 years; blood pressure cuffs and phlebotomy ties can serve as tourniquets, and sheets may substitute for pelvic binders. Early transfer to a pediatric trauma center is essential for definitive care [1].

Which pediatric trauma patients require blood products, and when should activation of a massive hemorrhage protocol be considered?

Identifying children requiring transfusion is based on signs of hemorrhagic shock and early physiologic indicators; tachycardia, delayed capillary refill, and altered mental status should prompt early transfusion consideration.

Activation of a massive hemorrhage protocol is assisted by multiple tools including the Pediatric Age-Adjusted Shock Index highly sensitive (98%) but poorly specific (23%) for predicting massive transfusion [3], the pediatric assessment of blood consumption score (Ped-ABC—sensitivity 77.4%, specificity 78.8%) and the Critical Administration Threshold, defined as ≥3 units in adults/adolescents or > 20 mL/kg of red blood cells in children within one hour, which is associated with mortality and urgent surgical needs (sensitivity 70%, specificity 77%) [4, 5].

What are the recommended blood transfusion ratios for pediatric hemorrhagic shock, and what is the role of low-titer group O whole blood?

Blood products—Red blood cells, frozen plasma, platelets, or low-titer group O whole blood—should be prioritized over crystalloid to optimize outcomes. A balanced transfusion strategy emulating whole blood and targeting plasma-to-red blood cell ratio of ≥1:2 are linked to higher survival rates, albeit limited prospective evidence exists in children [1]. Low-titer group O whole blood has thus far an excellent short-term safety profile in children, and offers several advantages over conventional component therapy, such as fewer transfusion exposures, lower volume requirements, more rapid shock reversal, and a simplified approach to balanced transfusion [6]. Pediatric studies suggest improved short-term survival when compared with conventional component therapy. Prospective clinical trials are needed in children prior to widespread use and are underway (https://www.matic2.org/).

The availability of whole blood in Canada is currently limited, further hindering its broader implementation [7, 8].

How applicable is permissive hypotension in pediatric trauma care?

Permissive hypotension in damage control resuscitation allows for a lower mean arterial pressure to reduce bleeding while maintaining organ perfusion. While potentially beneficial in adult trauma, it is not recommended for children due to their unique physiology and higher traumatic brain injury rates. It may be considered in adolescent penetrating trauma without traumatic brain injury, but current guidelines advise against routine pediatric use pending further research [2].

What roles do tranexamic acid, and other hemostatic agents play in hemorrhagic shock?

Tranexamic acid in pediatric trauma is considered safe, with no significant rise in thromboembolic risk, and may reduce mortality. Based on adult clinical trials and thus far limited pediatric data, it should be considered within 3 h of injury for traumatic hemorrhage requiring transfusion at a dose of 15–30 mg/kg (max 2 g) IV bolus, followed by 5–10 mg/kg/hr infusion over 8 h or until bleeding stops. Comparative studies of bolus-only versus bolus-plus-infusion regimens in children are lacking [1].

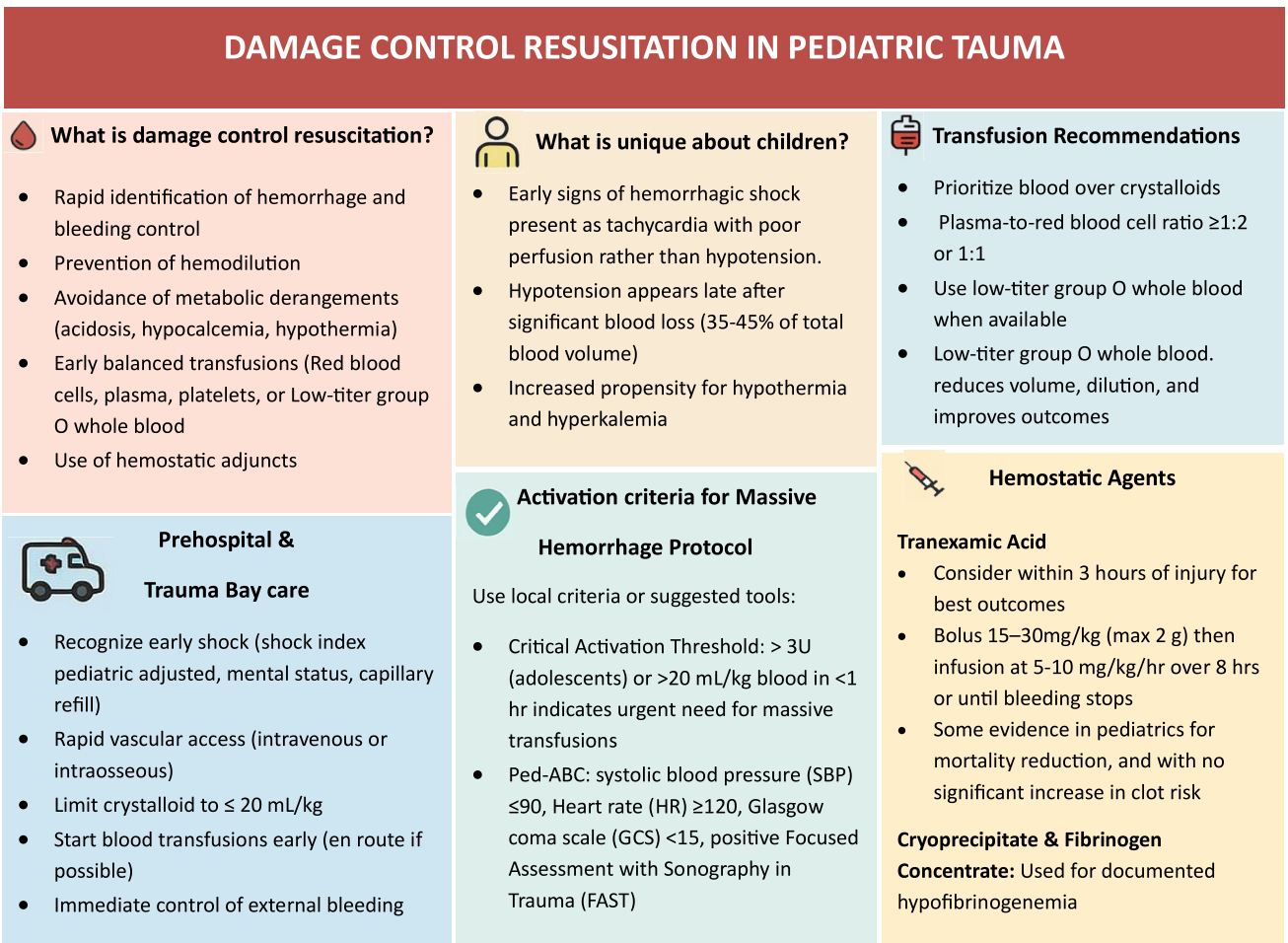
Both cryoprecipitate and fibrinogen concentrate are accepted options for treating trauma-related hypofibrinogenemia in children with active bleeding. Their use should be guided by laboratory-confirmed low fibrinogen levels, as adult data show no clear superiority or mortality benefit from early administration or empiric use of either product [9, 10].

Viscoelastic assays such as rotational thromboelastometry or thromboelastography are increasingly used in pediatric major hemorrhage to rapidly assess coagulation, guide transfusion, and enable goal-directed therapy. They provide real-time clot data, offering advantages over conventional tests, and are associated with faster coagulopathy treatment, reduced blood product use, and shorter hospital stays [1].

Case resolution

A massive hemorrhage protocol was activated due to continued hemodynamic instability (Pediatric Age-Adjusted Shock Index > 1.5) after receiving a critical administration threshold of 20 ml/kg of red blood cells with concerns for intra-abdominal bleeding given an expanding abdomen and positive FAST. Warmed red blood cells and plasma were rapidly administered via a rapid infuser in 10–20 ml/kg doses as close to a 1:1 ratio as able, and 10 ml/kg of platelets subsequently provided. Fibrinogen concentrate (50 mg/kg for initial fibrinogen level < 1.5 g/L) and calcium gluconate (60 mg/kg with first pack of the massive hemorrhage protocol) were administered, and tranexamic acid was dosed as a bolus of 15 mg/kg with a planned infusion if bleeding continued.

Despite aggressive resuscitation, the child's condition did not stabilize, prompting a decision for expedient transfer to the operating room for definitive control of the bleeding sources. Surgical hemostasis was achieved, the massive hemorrhage protocol was discontinued, and the child was transferred to the intensive care unit (ICU) before recovering uneventfully on the surgical ward.



Infographic

Data availability Not applicable

Declarations

Conflict of interests The authors declare that they have no conflicts of interest relevant to this manuscript.

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