

Chapter 5

Transfusion Medicine

Routine Transfusion Therapy

- Blood products should not be transfused on a unit basis in children
- Base the volume of transfusion products on weight to avoid over or under resuscitation
 - If only small-volume transfusions are needed, consider having the blood bank split a unit and save portions of it for later transfusion (24 h maximum); this will help avoid multiple donor exposures
 - Transfusing red blood cells (RBCs) that have been in storage for > 14 days has been associated with increased risk of organ failure in critically ill children; risk of immunologic, vasoregulation, and adverse hypercoagulation effects is also increased
- Estimated volume per unit of blood products is as follows:
 - Packed red blood cells (PRBCs): 300 mL/unit
 - Whole blood: 450–500 mL/unit
 - Fresh frozen plasma (FFP): 250–300 mL/unit
 - Platelets: 40–50 mL/unit
 - Cryoprecipitate: 10–12 mL/unit
- PRBCs
 - Initial volume of 10–15 mL/kg can be given quickly over minutes or over a 4-hour period, depending on the situation
 - The following equation can be used to determine the volume of PRBCs to transfuse; it requires the current hematocrit (HCT) level and the child's estimated blood volume (EBV; see Table 5-1 for average total blood volumes by age)

$$\frac{\text{desired HCT} - \text{present HCT}^* \times \text{EBV}}{\text{HCT of PRBC (avg 60\%–70\%)}}$$

*HCT of whole blood 40%–45%

Table 5-1. Blood Volume by Age

Age	Blood Volume (mL/kg)
Premature infant	100
Full-term neonate	85
Older infant	75
> 12 mo	70–75

- Transfusing a pediatric patient with 4 cc/kg will increase hemoglobin by 1 g/dL
- Transfusing 1 unit in an adult patient will raise hemoglobin by 1 g/dL (or HCT by 3%)
- FFP
 - Transfuse FFP 10–15 mL/kg
 - If close, round up or down to the closest unit
 - Routine FFP transfusion rates should not exceed 1 mL/kg/min because of the risk of hypotension caused by low ionized calcium during the FFP infusion
 - ▶ This complication can be treated with 10 mg/kg CaCl or 100 mg/kg calcium gluconate IV over 5–10 minutes
 - For patients with massive bleeding who are at risk for death secondary to hemorrhage, give FFP as fast as possible, paying attention to ionized calcium levels because large volumes of plasma and red cells will decrease ionized calcium concentrations
 - For patients with known clotting factor deficiencies, 10–15 mL/kg of FFP will raise factors levels 15%–20%
- Platelets
 - Pheresed platelet units have a volume of 6–10 random donor units
 - Transfuse 0.1–0.2 units/kg or 1 unit/5 kg of body weight
 - ▶ Equivalent to about 5–10 mL/kg
 - ▶ Increases platelet count by approximately 50,000/mm³
- Cryoprecipitate
 - An excellent source of fibrinogen and factor VIII, factor XIII, and Von Willebrand’s factor
 - Administering 1–2 bags for every 5–10 kg will raise fibrinogen levels 60–100 mg/dL

Massive Transfusion Therapy for Severe Hemorrhagic Shock

- The principles of damage-control resuscitation developed for adults are generally applicable in massively bleeding children
 - Current policies regarding hemorrhagic-shock resuscitation, regarding the use of whole blood and recombinant factor VIIa, are appropriate to guide therapy for children with severe injuries
- A “massive transfusion” in a child is when approximately one circulating blood volume is replaced within 24 hours
 - Consider using massive transfusion strategies when a child is anticipated to need more than two traditional 15 mL/kg transfusions of PRBCs during one resuscitation (equivalent to about > 6–8 PRBC units for an adult)
- Some clinical parameters may predict the need for a massive transfusion during active bleeding
 - Severe tachycardia or hypotension for age
 - Base deficit ≥ 6
 - Lactate ≥ 4 mmol/L
 - International normalized ratio ≥ 1.5
 - Hemoglobin ≤ 9 g/dL upon admission
- When transfusing through small IV catheters (22 gauge and 24 gauge), bolusing with a 10–20 mL syringe may be the most efficient way to deliver fluids and blood products rapidly
- If a patient is at risk for massive transfusion, PRBCs, FFP, and platelet transfusion should be initiated in a 1:1:1 ratio
 - Helps avoid coagulopathy and is associated with reduced mortality from hemorrhage in adults
 - Use of blood products in this ratio should continue until the life-threatening bleeding has stopped; at this point use more restrictive transfusion criteria. Formulas for calculating volumes of each product should be used
- Fresh warm whole blood (FWWB)
 - If FWWB is available, consider using it as a substitute for PRBCs, FFP, and platelets
 - FWWB can be beneficial in the massively transfused patient
 - ▶ Decreases the likelihood of hypothermia
 - ▶ Avoids the deleterious effects of large volumes of old stored RBCs and the accompanying anticoagulants

and preservatives

- FWWB is particularly helpful when platelets or other component therapy is unavailable
- Risk of transmitting infection and minor blood group incompatibilities is increased
- Transfuse 15–20 mL/kg; repeat as necessary
- Watch for hypocalcemia and hyperkalemia
- Factor VIIa has been used to reduce blood loss and restore hemostasis in combat casualties with coagulopathy associated with hemorrhagic shock
 - Works best with a pH > 7.1, a platelet count > 50,000/mm³, and a fibrinogen level > 100 g/L
 - Has been used successfully in pediatric trauma for patients requiring massive transfusion
 - Dose is 90 µg/kg and may be repeated if persistent bleeding occurs secondary to coagulopathy within 1–3 hours

Risks Associated with Pediatric Transfusions

- Hyperkalemia
 - Potassium escapes from RBCs as they age; therefore, older units of PRBCs may contain high levels of potassium
 - Pediatric patients have small blood volume, so a potassium load results in a higher risk of hyperkalemia
 - Transfusion-associated hyperkalemic cardiac arrest is almost always associated with a low cardiac output state, acidosis, hyperglycemia, hypocalcemia, and hypothermia; all conditions commonly found in patients requiring massive transfusion
 - Avoiding older blood products and closely monitoring electrocardiogram (ECG) morphology and serum potassium can help avoid hyperkalemic cardiac arrest
- Hypocalcemia
 - Children are particularly prone to hypocalcemia secondary to citrate-containing blood products
 - Transfusion-related hypocalcemia is most likely to be caused by FFP and whole blood because these products contain the most citrate per unit volume
 - ▶ Monitor for hypocalcemia if FFP is transfused > 1 mL/kg/min

- ▶ Ca^{2+} is a potent inotrope in infants and children; severe cardiac depression and hypotension can result from ionized hypocalcemia
 - ▷ Potent inhalational agents dramatically exacerbate this hypotension
- ▶ Prevention includes limiting the rate of FFP transfusion to $< 1 \text{ mL/kg/min}$ if feasible and administering calcium chloride (5 mg/kg) or calcium gluconate (15 mg/kg)
- Hypothermia
 - This is a significant risk given pediatric surface-area-to-weight ratios
 - Consider using blood warmer, especially if large volumes will be transfused
- The risks of bacterial and viral contamination are the same as in adults
- Fluid overload
 - Patients with chronic anemias (eg, sickle cell anemia) undergoing transfusion are at risk for fluid overload and congestive heart failure
 - Use slow transfusions (1 cc/kg/h)
 - Consider administering furosemide ($0.25\text{--}0.5 \text{ mg/kg}$) midtransfusion or after transfusion

Special Preparations (consider if available)

- Leukocyte-reduced blood products
 - Used to prevent febrile, nonhemolytic transfusion reactions
 - Microaggregate filters prevent febrile transfusion reactions and are useful in patients who have received blood frequently in the past
 - Leukopore filters are needed to decrease risk of cytomegalovirus transmission and human leukocyte antigen alloimmunization
 - White blood cell filters will dramatically slow the rate of a transfusion (may not be appropriate during a transfusion for hemorrhagic shock because of active bleeding)

Further Reading

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