Transfusion guidelines in children: I

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Abstract

The transfusion of a blood product to a child is associated with a greater risk of harm when compared to an adult. Transfusion is necessary in certain situations and so the benefits have to be balanced against potential adverse events. This article will present information concerning blood transfusion thresholds in children, calculations for maximal tolerated blood loss and the concept of massive transfusion protocols.

Keywords Anaemia; children; haematocrit; haemoglobin; massive transfusion protocols; maximum allowable blood loss; transfusion; transfusion thresholds

Royal College of Anaesthetists CPD Matrix: 1B01, 1E04, 1A02, 2A05, 3D00, 2D04, 2D05

Learning objectives

After reading this article, you should be able to:

- appreciate the different transfusion thresholds for children with different pathologies
- calculate the maximal allowable blood loss for a fit and well child with a normal preoperative haemoglobin concentration
- calculate the estimated haematocrit according to a measured haemoglobin concentration
- appreciate the use of massive transfusion protocols in major haemorrhage

Blood has many interrelated functions including oxygen carriage, haemostasis, drug metabolism and immunity. Consequently the ability to replace blood with a practical artificial component has so far eluded researchers. A change in the circulating blood volume and cellular components affects all these functions in addition to cardiovascular effects.

The Paediatric Perioperative Cardiac Arrest Registry showed that the most common cause of cardiac arrest during anaesthesia was hypovolaemia secondary to blood loss. Most of these occurred during cranial and spinal surgery.[1] The effects of uncompensated hypovolaemia can range from minor organ dysfunction without clinical sequelae to multi-organ failure requiring invasive support. Hypovolaemia should always be identified and managed promptly. Conversely, hypervolaemia is associated with different intraoperative and postoperative complications. Consequent interstitial and alveolar oedema can impair wound closure and healing, inhibit gastrointestinal function and slow artificial ventilation weaning in critical care; all contributing to patient morbidity and increased hospital stay.

What are the normal haematological parameters in children?

At birth the haemoglobin concentration is usually at its greatest, particularly if clamping of the umbilical cord is delayed. This usually falls to a concentration of 80–90 g/l by 3 months of age due to a decreased red cell production (Table 1). Platelet numbers are normal at birth; however, they may have impaired function for the first 2–4 weeks. There are both quantitative and qualitative deficiencies of multiple haemostatic proteins in both neonates and infants and this is reflected in both a prolonged prothrombin time (PT) and activated partial prothrombin time (APTT), particularly in preterm babies. Fibrinogen concentrations are normal but qualitatively dysfunctional. Normal concentrations and function are reached by 6 months to 1 year of age. Despite this, under normal circumstances, they show no increased signs of bruising or bleeding during surgery. Critical illness can disrupt the haemostatic balance, unpredictably leading to either haemorrhagic or thrombotic complications.

Normal haematological ranges

	Preterm	Term	Adult
Haemoglobin (g/dl)			
Birth	14–24	14–24	–
3 months	8–14	8–14	–
6 months–6 years	10–14	10–14	–
7–12 years	11–16	11–16	–
Adult	–	–	11.5–18
Platelets ($\times 10^9$/l)	150–450	150–450	150–400
PT (sec)	11–22	10–16	11–14
APTT (sec)	28–101	31–55	27–40
Fibrinogen (g/l)	1.5–3.7	1.7–4.0	1.5–4.0
Blood Volume (ml/kg)	90–100	80–85[a] 75–80[b]	65–75

PT, prothrombin time; APTT, activated partial thromboplastin time.
[a] Blood volume at birth.
[b] Blood volume by 6 months of age.

Table 1

How low can you go?

The studies performed to assess the threshold at which anaemia becomes detrimental have helped to prevent unnecessary blood transfusion. The use of transfusion thresholds (concentration of haemoglobin below which transfusion is considered) reduces exposure to donor blood without increasing morbidity and mortality.

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Healthy children should maintain tissue oxygen delivery despite a fall in haemoglobin concentration to 70 g/l providing they have a normal cardiac output.[2] Assuming that the child remains haemodynamically stable and further bleeding is unlikely, blood transfusion is not indicated. There may be a role for iron supplementation in children with postoperative iron deficiency anaemia. If acute ongoing haemorrhage occurs a higher transfusion threshold may be chosen to avoid a delay between decision to transfuse and administration.

Acute reductions in haemoglobin to below 70 g/l are tolerated and lower transfusion thresholds are used in parts of the world where blood supply is limited and safety uncertain. Chronic reductions in haemoglobin are tolerated due to cardiovascular, respiratory and renal compensation. Acute normovolaemic haemodilution in healthy resting adults to 50 g/l was not associated with inadequate oxygen delivery; however, it was associated with tachycardia, decreased memory and higher cerebral function, suggesting that cellular oxygen delivery may be borderline. Cognitive function returned to normal when haemoglobin was increased to 70 g/l or when oxygen therapy was administered.[3]

The majority of research guiding transfusion thresholds are from adult cohorts. Several studies have compared the use of restrictive and liberal blood transfusion guidelines in paediatric intensive care units, finding no clinical benefit from liberal transfusion.[4] Excluding preterm infants, a restrictive policy is not associated with an increase in adverse events providing they are haemodynamically stable.[5]

Certain groups of children require a higher transfusion threshold, e.g. neonates, infants, children with cyanotic congenital heart disease, chronic lung disease and haemoglobinopathies (Table 2). Haemolysis of fetal haemoglobin occurs within the first month of life leading to a reduction in haemoglobin concentration. The neonatal heart has a limited ability to increase cardiac output. When stressed due to concurrent illness or anaemia neonates may decompensate causing apnoea, failure to thrive and rarely cardiac ischaemia.

It has been suggested that strict adherence to thresholds was not possible within paediatric subgroups and an appreciation for requirements in different pathologies must be retained.[6] In children with univentricular physiology and in critically ill children with a haemoglobin concentration between 50 and 70 g/l the transfusion threshold remains to be determined.[7] Patients should be considered individually in the context of their illness.

What is the maximum allowable blood loss?

Emergency situations may provide a challenge, as the initial haemoglobin concentration may be reflective of a chronic state or

Transfusion thresholds

Blood product	Clinical condition	Transfusion threshold
RBC	**Infant <4 months of age**	**Haemoglobin**
	Preterm/term born anaemic	12 g/dl
	Chronic oxygen dependency	11g/dl
	Severe pulmonary disease	12–14 g/dl
	Late anaemia stable patient	7g/dl
	Acute blood loss >10% EBV	12g/dl
RBC	**Infant >4 months of age**	**Haemoglobin**
	Stable infant	7 g/dl
	Infant/child critically unwell	7–8 g/dl
	Infant/child with peroperative bleeding	8 g/dl
	Infant/child with Cyanotic Congenital Heart Disease (have an increased oxygen demand)	9 g/dl
	Child with Thalassaemia Major (to slow bone marrow stimulation)	9 g/dl
	Child with SCD (>9 g/dl if previous CVA)	7–9 g/dl
	Child with SCD for major surgery (aim for 9–11 g/dl and HbS <30%, <20% for thoracic or neurosurgery)	9 g/dl
Platelets		**Platelets**
	Neonate with bleeding	50×10^9/l
	Sick neonate not bleeding	30×10^9/l
	Stable neonate not bleeding	20×10^9/l
	Stable infant >4 months/child	10×10^9/l
	Infant/child ICU	20×10^9/l
	Any infant/child for an invasive procedure or surgery	$50–100 \times 10^9$/l
FFP		**Coagulation**
	Neonate/child with bleeding	APTT and PT >1.5 control for age
	DIC or prior to an invasive procedure	
Cryoprecipitate	Neonate/child with bleeding or DIC not corrected with FFP	Fibrinogen <1 g/l

SCD, sickle cell disease; HbS, sickle haemoglobin; ICU; intensive care unit; DIC, disseminated intravascular coagulation; APTT, activated partial thromboplastin time; PT, prothrombin time; FFP, fresh frozen plasma.

Table 2

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