

## **Paediatric Patient Blood Management: A Forgotten Population?**

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### **Abstract**

Patient blood management (PBM) is a multidisciplinary, evidence-based approach to the preservation and optimisation of a patient's own blood, minimising avoidable blood loss, supporting physiological anaemia tolerance, and reducing unnecessary exposure to transfusion. Paediatric PBM is focused on optimising and preserving the child's blood health throughout perioperative care and development. Moreover, neonates, infants, children, and adolescents have unique considerations with individualised physiological development; predisposition for anaemia of different aetiologies; and distinct biological responses to anaemia, blood loss, and blood transfusion. In this review, we examine how the three main pillars of PBM can be adapted across the paediatric age-specific perioperative setting. Key paediatric-specific considerations include the high rate of undiagnosed iron deficiency before surgery, the impact of frequent iatrogenic blood extractions for samples and circuit-related losses, blood product dosing and volume safety and accuracy, limited paediatric-grade evidence for available adjunctive therapies, and marked variability in global and institutional infrastructure to support PBM initiatives. Current evidence and expert consensus reinforce individualised management based on physiological and biological markers and point-of-care variables. Importantly, these considerations specific to children need to be proactively addressed and differentiated for all phases to promote safe and effective implementation of paediatric PBM.

**Key words:** blood transfusion, perioperative, haemoglobin, anaemia, iron, haemorrhage, antifibrinolytics agents

### **INTRODUCTION**

Patient blood management (PBM) is a patient-centred, evidence-based, multidisciplinary strategy endorsed by the World Health Organisation (WHO) to improve outcomes through optimisation and preservation of the patient's own blood.<sup>1</sup> PBM emerged from recognition that blood transfusion, while lifesaving, is associated with dose-dependent complications, increased morbidity, and substantial healthcare costs.<sup>1,2</sup> Supported by a robust adult evidence base, PBM has evolved into a formalised, pathway-driven paradigm structured around three pillars: optimisation of haemoglobin and red cell mass, minimisation of blood loss and bleeding, and optimisation of physiological tolerance of anaemia through restrictive, physiology-guided transfusion practices.<sup>1-3</sup> The core components of PBM are summarised in Figure 1. In many settings, paediatric patients continue to be cared for with patient blood

management (PBM) strategies derived from adults. Such strategies are frequently misaligned with certain unique characteristics of children: age-specific coagulation development, smaller blood volume, neonatal physiology, the presence of congenital cardiovascular defects, and metabolic capacity, together with conditions such as prematurity, congenital heart disease, malignancy, chronic inflammation, and nutritional iron deficiency, necessitate paediatric-specific approaches to transfusion decision making.<sup>1,4</sup> Moreover, this remains a challenge in low- and middle-income countries, where limited resources worsen deficiencies in available means to promote paediatric blood health.

The key challenge for paediatric and perioperative multidisciplinary teams is therefore not whether PBM principles apply to children but how these principles can be translated into paediatric appropriate definitions,

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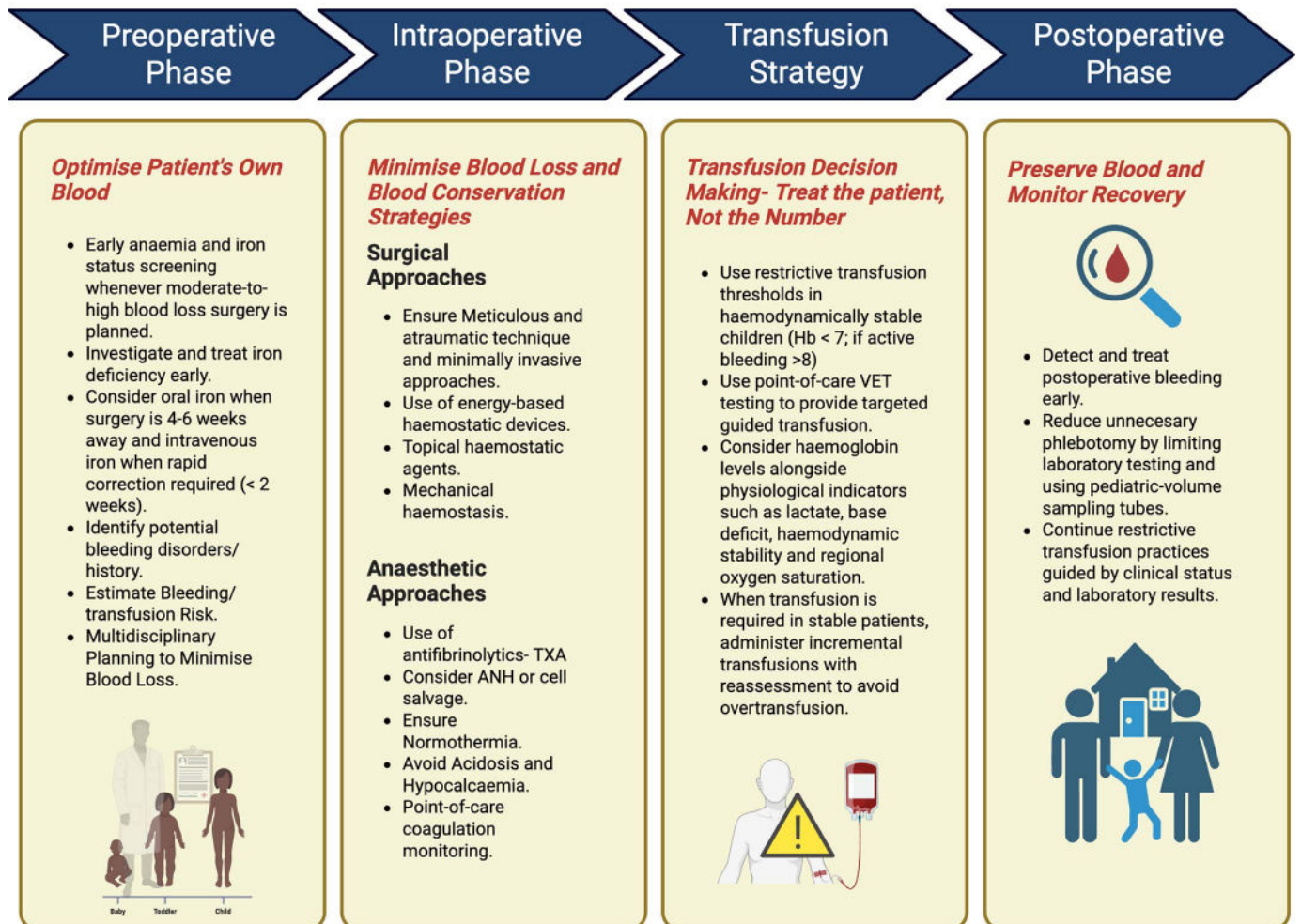
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# Practical Paediatric PBM Perioperative Pathway: A Quick Clinical Guide



**Figure 1** – Practical Paediatric PBM Perioperative Pathway: A Quick Clinical Guide. Source: Created in BioRender. Echeto, M. A. (2026), <https://BioRender.com/86nlng>.

processes, and decision support tools that minimise avoidable transfusion while ensuring access to blood when clinically necessary. This article reviews the principles of paediatric patient blood management and proposes a pragmatic framework for its application in clinical practice.

## PREOPERATIVE PAEDIATRIC PBM

The preoperative period provides an opportunity to improve blood health in children through early detection and management of anaemia and iron deficiency, and the identification and correction of coagulopathy where possible (Figure 1).

### Preoperative Screening

Preoperative anaemia in children is common and associated with increased perioperative morbidity, mortality, and transfusion exposure. Reported prevalence varies widely depending on the surgical population and screening practices, ranging from 24.3% globally<sup>5</sup> to 42% in less than five year-old children.<sup>6</sup> However,

most data derive from selectively tested cohorts, potentially underestimating the true burden of anaemia in paediatric surgical populations. Early identification of anaemia enables optimisation of red cell mass before surgery. In adult perioperative care, near-universal haemoglobin screening is widely recommended.<sup>7,8</sup> In children, guidance remains more conservative, often restricting testing to major surgery or to those with significant comorbidity. While this approach aims to limit unnecessary testing, it may miss opportunities for intervention, particularly in settings with a high prevalence of childhood anaemia. Point-of-care haemoglobin testing comes handy and provides a rapid assessment with minimal infrastructure and may be particularly useful in resource-constrained settings, although recognised accuracy limitations remain.<sup>8-10</sup> Laboratory full blood count testing remains the reference standard. Anaemia is defined as haemoglobin below the lower limit of normal for age, commonly approximated by the fifth percentile of the population distribution. The World Health Organization also provides pragmatic

**Table 1** – WHO definitions of anaemia and iron deficiency in children and adolescents

Age Group	Threshold
Anaemia (Haemoglobin, g·dL <sup>-1</sup> ) <sup>11</sup>	
6–23 months	<10.5
24–59 months	<11.0
5–11 years	<11.5
12–14 years	<12.0
≥15 years (female)	<12.0
≥15 years (male)	<13.0
Iron deficiency (Ferritin, µg·L <sup>-1</sup> ) <sup>12</sup>	
<5 years — no inflammation	<12
≥5 years — no inflammation	<15
Any age — inflammation / elevated CRP	<30

Abbreviations: Hb, haemoglobin; CRP, C-reactive protein; WHO, World Health Organization.

<sup>†</sup> World Health Organization. WHO guideline on haemoglobin concentrations for the diagnosis of anaemia and assessment of severity. Geneva: WHO; 2024.

<sup>‡</sup> World Health Organization. WHO guideline on use of ferritin concentrations to assess iron status in individuals and populations. Geneva: WHO; 2020.

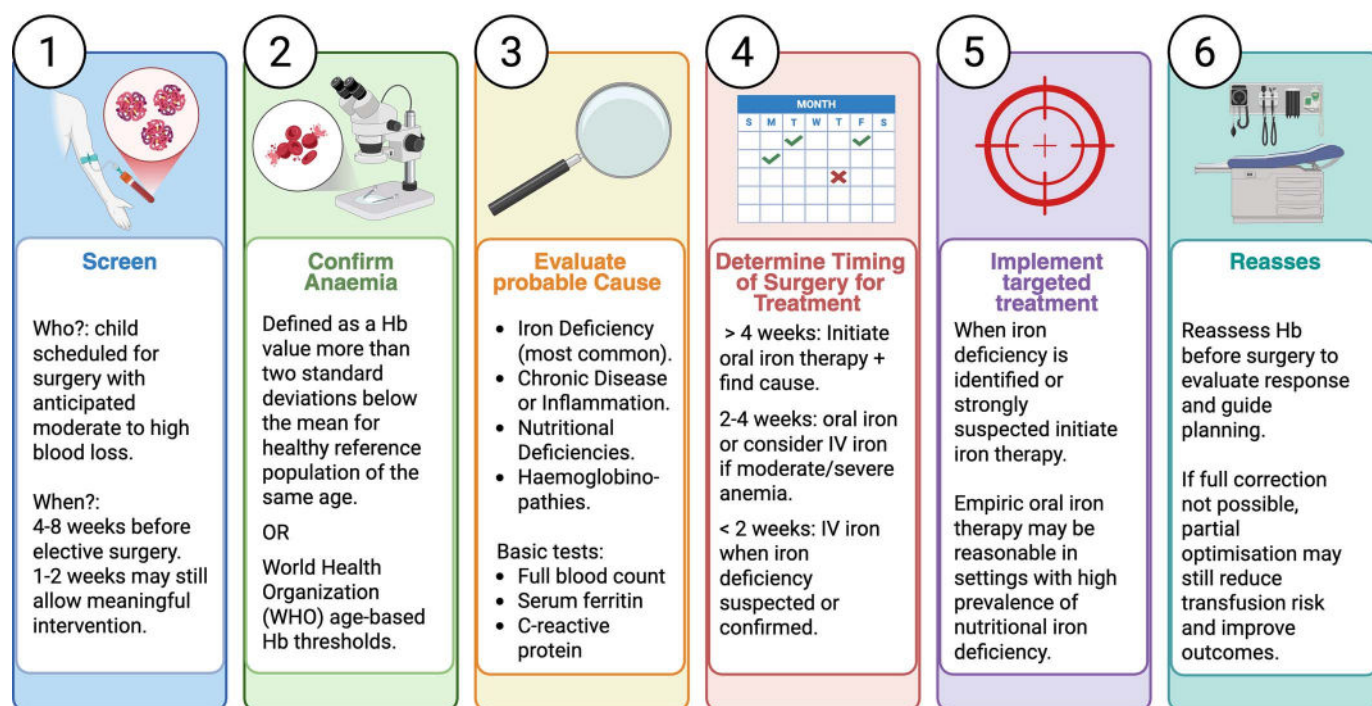
age-specific haemoglobin thresholds widely used for clinical screening and epidemiological reporting. (Table 1)<sup>11,12</sup> Point-of-care haemoglobin testing may support rapid assessment in resource-constrained settings, although accuracy limitations remain, particularly with capillary

sampling. Iron deficiency assessment commonly relies on serum ferritin concentrations.<sup>8–10</sup> Iron deficiency is indicated by a ferritin level of less than 12 ng/mL (mcg/L) in children under five and less than 15 ng/mL in those over five.<sup>11</sup> Interpretation may be complicated by inflammation, particularly in populations with infection, malaria, or haemoglobinopathies. Paediatric age-specific haemoglobin thresholds are available and required to inform safe and effective screening pathways.

### Management of Preoperative Anaemia

Management following diagnosis should be guided by underlying causes. (A practical screening and management pathway for preoperative anaemia is illustrated in Figure 2). Although the aetiology in paediatric surgical populations is incompletely characterised, iron deficiency remains the most common cause globally and an important initial target for intervention. Iron deficiency may occur with or without anaemia and may reflect nutritional deficiency, chronic inflammation, parasitic infection, or other comorbid conditions. In many settings, empiric oral iron therapy represents a pragmatic and widely accessible approach to improving haemoglobin levels before surgery, often combined with deworming where helminth infection is prevalent. Intravenous iron may be considered in selected children when oral therapy is ineffective, poorly tolerated, or when surgery is imminent and more rapid haemoglobin optimisation is required.<sup>13</sup> Erythropoiesis-stimulating agents may also be used in specific circumstances, although their use is limited by cost, availability, and variable access across healthcare settings. Newer intravenous iron preparations such

## 6 - Step Practical Approach to Preoperative Anaemia Management



**Figure 2** – Six step practical approach to preoperative anaemia management. Source: Created in BioRender. Echeto, M. A. (2026), <https://BioRender.com/86nlng>.

**Table 2** – Iron Formulations and Dosages

	<b>Formulation</b>	<b>Approved Pediatric Indications</b>	<b>Dosage</b>	<b>Maximum Dose</b>
Oral Iron	<i>Ferrous Salts (e.g., Sulfate Fumarate)</i>	All ages (Infants to Adolescents)	Mild anemia 2-3 mg·kg <sup>-1</sup> per day divided in 2-3 doses* Severe anemia 3-6 mg·kg <sup>-1</sup> per day divided in 2-3 doses	> 50 kg: 150-200 mg/day Divide into 2–3 doses or once daily to improve adherence. Toxicity > 20 mg·kg <sup>-1</sup>
	<i>Iron polymaltose Complex</i>	All ages (Infants to Adolescents)	3-5 mg·kg <sup>-1</sup> per day as a single dose or divided	Children: 100 mg per day Adolescents: 200 mg per day
	<i>Sucrosomial Iron (or Bisglycinate)</i>	All ages (Infants to Adolescents)	1-3 mg·kg <sup>-1</sup> per day (often requires lower dose due to high absorption)	30-60 mg per day (highly bioavailable)**
IV Iron	<i>Iron Sucrose</i>	Children ≥2 years with CKD dialysis or non-dialysis dependent receiving erythropoietin therapy	0.5 mg·kg <sup>-1</sup> in 60 min	Initial dose: Max.100 mg per dose every 2 weeks (dialysis dependent) or 4 weeks (non-dialysis dependent) patients. Commonly used off-label for HMB.
	<i>Iron Dextran (LMWD)</i>	Children > 4 months	Dose (mL) = 0.0442 x (Target Hgb - Observed Hgb) x LBW + (0.26 x LBW).	Until calculated dose with Ganzoni*** is given. Approved: 100 mg per infusion. Total Dose Infusion: Up to 1000 mg (off-label). Requires test dose.
	<i>Ferric Carboxymaltose</i>	Children > 1 year with IDA	< 50 kg: 15 mg·kg <sup>1</sup> /dose in 15-30 min (2 doses separated by at least 7 days) ≥ 50 kg: 750 mg/dose (2 doses separated by at least 7 days)	750 mg 1000 mg as a single infusion (associated with hypophosphatemia)
	<i>Ferric Gluconate</i>	Children ≥6 years with CKD on dialysis and EPO therapy	1.5 mg·kg <sup>1</sup> of elemental iron in 60 min	125 mg per dose

Adapted from Cohen and Powers 2023.

\* Dosing Schedule: While the chart mentions divided doses (standard for ferrous salts), modern guidelines often recommend once-daily or every-other-day dosing to reduce “hepcidin” blockade and improve long-term adherence.

\*\* Bioavailability: New formulations use a “phospholipid bilayer” to bypass the usual absorption barriers in the gut. Usually same results with a lower dose compared to traditional salts, with significantly fewer GI side effects.

\*\*\* Ganzoni Formula:

Total Iron Deficit (mg) = [Weight (kg) x (Target Hb - Actual Hb in g·dL<sup>-1</sup>) x 2.4] + Iron Stores (mg). Iron stores = 15 mg·kg<sup>-1</sup> max 500 mg. Use target Hb of 15 g·dL<sup>-1</sup>

Response Monitoring: An optimal response to iron therapy is indicated by reticulocytosis within 5–7 days, followed by a rise in hemoglobin within 1–2 weeks.

Abbreviations: HMB: Heavy Menstrual Bleeding; CKD: Chronic Kidney Disease; IDA: Iron Deficiency Anaemia; EPO: Erythropoietin

as ferumoxytol and ferric iron gluconate demonstrate improved safety profiles compared with older formulations.<sup>14</sup> Table 2 lists the routes and frequently used iron compositions.

### Coagulopathy Assessment

Coagulopathy is an underrecognised contributor to perioperative risk in children. Assessment is complicated by developmental haemostasis, age-dependent reference ranges, and variable access to specialised testing. Current guidance recommends an initial structured clinical evaluation, including a detailed personal bleeding history, family history of bleeding disorders, and review of medications that may affect haemostasis.<sup>13</sup> This assessment remains the most important screening tool for identifying children at risk of inherited bleeding disorders. Laboratory investigations should

therefore be targeted rather than routine. When indicated, testing may include basic coagulation studies or specific factor assays guided by clinical findings, with management focused at identifying and correcting reversible causes such as vitamin K deficiency or liver dysfunction.

### INTRAOPERATIVE PAEDIATRIC PBM

Children, particularly neonates and infants, have limited physiological tolerance to anaemia, an underdeveloped coagulation system, and smaller circulating blood volumes than adults. Age-specific, evidence-based approaches that strike a balance between the necessity for haemostasis and the avoidance of transfusion-related hazards, are the need of the hour. The intraoperative PBM aims to focus on blood conservation strategies, and optimisation of

**Table 3** – Pragmatic haemoglobin thresholds for red blood cell transfusion in neonates, infants, and children

Population/Clinical Context	Hb Threshold (g·dL <sup>-1</sup> )	Key Evidence
Extremely low birth weight preterm neonates (birth weight ≤1000 g)		
No respiratory support		
Postnatal week 1	<10	TOP <sup>32</sup> ; ETTNO <sup>33</sup>
Postnatal week 2	<8.5	TOP <sup>32</sup> ; ETTNO <sup>33</sup>
Postnatal week ≥3	<7	TOP <sup>32</sup> ; ETTNO <sup>33</sup>
Respiratory support		
Postnatal week 1	<11	TOP <sup>32</sup> ; ETTNO <sup>33</sup>
Postnatal week 2	<10	TOP <sup>32</sup> ; ETTNO <sup>33</sup>
Postnatal week ≥3	<9	TOP <sup>32</sup> ; ETTNO <sup>33</sup>
Infants and children (>28 days)		
Haemodynamically stable critically ill child without significant cardiopulmonary disease	<7	TRIPICU <sup>34</sup> ; TAXI <sup>35</sup>
Stable child after biventricular congenital heart surgery	<7	TAXI <sup>35</sup>
Single-ventricle physiology	<9	TAXI <sup>35</sup>
Cyanotic congenital heart disease without complete repair	7–9	TAXI <sup>35</sup>
Transfusion recommended	<5	TAXI <sup>35</sup>
<i>Actively bleeding Child</i>	<8	TAXI <sup>35</sup>

Abbreviations: Hb, haemoglobin; TOP, Transfusion of Prematures trial; ETTNO, Effects of Transfusion Thresholds on Neurocognitive Outcome trial; TRIPICU, Transfusion Requirements in Paediatric Intensive Care Units trial; TAXI, Transfusion and Anemia Expertise Initiative.

Respiratory support definitions follow those used in the TOP and ETTNO trials: respiratory support included invasive mechanical ventilation, continuous positive airway pressure (CPAP), nasal intermittent positive-pressure ventilation, or nasal cannula ≥1 L·min<sup>-1</sup>; no respiratory support included room air or nasal cannula <1 L·min<sup>-1</sup>

physiological tolerance of anaemia through restrictive, physiology-guided transfusion practices, recognising transfusion as a supportive therapy rather than a primary treatment (Figure 1).<sup>15</sup>

### Blood Conservation Strategies

Intraoperative blood loss is a complex problem, as it primarily includes surgical bleeding, and iatrogenic losses mostly related to phlebotomy, investigations, and during establishing vascular access especially central vascular access. Both surgeons and anaesthesiologists significantly contribute towards the blood conservation strategies. (Figure 1). Although patient safety remains paramount, unnecessary blood loss should be minimised through careful preoperative and intraoperative planning. Pragmatic paediatric blood conservation strategies include meticulous surgical haemostasis, avoidance of excessive sampling, advanced monitoring guided physiological optimisation, use of antifibrinolytics, cell salvage, and use of point-of-care testing where appropriate to guide management (Table 3).

### Advanced Monitoring Guided Physiological Optimisation

Maintenance of physiological homeostasis during bleeding, particularly avoidance of haemodilution, hypothermia, and acidosis, is central to preserving coagulation and limiting blood loss. Emerging evidence supports the use of advanced monitoring technologies, especially in neonates, to enable more precise assessment of oxygen delivery and consumption.<sup>16–18</sup> Near-infrared spectroscopy used alongside haemodynamic and biochemical markers such as lactate,

base deficit, and pH may support physiology-guided decision making in high-risk settings. Cerebral and somatic oximetry, when available, provides valuable information on end-organ oxygen delivery and may be compromised in hypotensive and anaemic patients.<sup>19</sup> Evolving evidence does not support the historically implemented deliberate hypotension in the paediatric population, as this has not been shown to confer benefit.<sup>1</sup>

### Prophylactic use of Antifibrinolytics

Tranexamic Acid (TXA) is an antifibrinolytic medication, that acts by competitively inhibiting the lysine-binding site on plasminogen molecule, preventing activation of plasmin, and therefore stabilizing the fibrin clot against degradation. At higher doses, TXA is a direct inhibitor of plasmin. TXA is an inexpensive, universally available and highly effective antifibrinolytic agent for reducing blood loss in paediatric surgery where bleeding is anticipated, such as cardiac surgery, spinal fusion, craniosynostosis repair, and major trauma. TXA should be considered prophylactically for any patient in whom >10% of estimated blood loss is anticipated or therapeutically for any patient with active significant bleeding.<sup>20</sup> In paediatric pharmacokinetic studies, administration of an intravenous bolus between 10 and 30 mg/kg followed by an infusion of 5–10 mg/kg/h has been associated with reduced intraoperative blood loss and transfusion requirements, without an increase in serious adverse events.<sup>21</sup> It should be noted that TXA is a clot stabiliser, not a clot promoter, and prospective paediatric studies support the

low thromboembolic risk. Expert consensus recommendations support routine consideration of antifibrinolytic therapy as part of intraoperative PBM.

### **Acute Normovolaemic Haemodilution**

Acute normovolaemic haemodilution (ANH) may be considered in selected paediatric patients when substantial blood loss is anticipated, provided the starting red blood cell (RBC) mass is amenable to an intraoperative presurgery “donation” with normovolaemic replenishment using crystalloids or colloids.<sup>22</sup> ANH may be a desired blood conservation modality when alternative PBM strategies are limited by patient or institutional factors. The technique involves a precalculated and controlled volume withdrawal of whole blood, monitoring haemodynamics, and with a 1:1 replacement volume to safely reduce the haematocrit prior to surgical bleeding. The whole blood is anticoagulated, kept at room temperature to preserve the platelets and reinfused within 8 hours.<sup>23</sup> Evidence supporting ANH in children remains limited to major surgeries like cardiac surgeries resulting in reduction of the transfusion requirement intraoperatively and postoperatively but minimal evidence to show any long term benefit.<sup>24</sup>

### **Cell Salvage**

Cell salvage is an effective strategy for preserving autologous red cells in paediatric surgery when significant blood loss is anticipated or in children with rare blood groups where compatible donor blood may be difficult to source. By collecting and reinfusing shed blood, cell salvage can reduce exposure to allogeneic transfusion. Technological advances, including lower priming volumes and paediatric-specific circuits, have improved feasibility across a range of paediatric surgical settings. Observational data suggest that in children weighing >10 kg who lose >10% of total circulating volume, cell salvage is most successful. Volumes as low as 50 mL can be recovered by careful salvage procedures as well as using new devices. Strategies for improving collection include avoiding turbulent suctioning on the surgical field, which can lead to RBC lysis; minimising blood lost in drapes and surgical sponges; and using paediatric collection bowls.<sup>25</sup>

Cell salvage remains limited by cost, equipment availability, and operator experience, particularly in resource-constrained settings. Effective implementation requires coordination between surgical and anaesthetic teams and familiarity with paediatric-specific considerations. Although high-quality randomised data are lacking, observational studies indicate that cell salvage is associated with reduced allogeneic transfusion in children undergoing surgery with anticipated major blood loss.<sup>26</sup>

### **Surgical Strategies**

Safe, effective, and meticulous surgical technique is central to intraoperative blood conservation and includes minimally invasive approaches, staged procedures, meticulous dissection, and judicious use of haemostatic methods such as electrocautery, manual compression, and suture ligation. Topical haemostatic agents<sup>27,28</sup> such as fibrin sealants Gelfoam, Floseal, and fibrin glue also help to attain local haemostasis.

### **Bleeding Management**

During major intraoperative bleeding, structured management combining clinical assessment with laboratory or point-of-care testing may support targeted haemostatic therapy.<sup>29</sup> Viscoelastic testing (e.g. thromboelastography or rotational thromboelastometry) enables dynamic assessment of clot formation and earlier identification of coagulopathy. Evidence is strongest in paediatric cardiac surgery, with more limited data in other surgical populations.<sup>30</sup> Hypofibrinogenaemia is an important predictor of bleeding risk in major paediatric surgery, and fibrinogen replacement using cryoprecipitate or fibrinogen concentrate may be required.<sup>31</sup> Prothrombin complex concentrates and recombinant activated factor VII may reduce bleeding in selected situations but carry potential thrombotic risk and should generally be reserved for carefully selected cases.<sup>30,32</sup> A pragmatic bleeding management algorithm is illustrated in Table 3.<sup>29,32–35</sup>

### **POSTOPERATIVE BLOOD MANAGEMENT STRATEGIES**

Postoperative PBM emphasises optimisation of blood health, early recognition of bleeding, and minimisation of iatrogenic blood loss. Careful monitoring of bleeding is essential, with early surgical review when concerns are expressed. Efforts should reduce unnecessary phlebotomy through judicious testing, smaller tubes, and avoidance of routine sampling. Postoperative blood recovery from drains may reduce donor exposure, although paediatric data remain limited. Restrictive transfusion practices remain central. Platelet and plasma transfusion should be guided by clinical context and laboratory findings, with viscoelastic testing supporting targeted correction where available.<sup>29</sup>

### **IMPLEMENTATION CHALLENGES**

Despite increasing recognition of patient blood management principles, implementation in paediatric practice remains variable. The evidence base is limited and many recommendations rely on observational data and expert consensus. Application is further complicated by developmental haemostasis, smaller circulating blood volumes, neonatal physiology, and congenital cardiac disease, which influence bleeding risk and tolerance of anaemia. Resource constraints add additional challenges, particularly in low- and middle-income settings where laboratory capacity, blood product availability, and access to therapies may be limited. A pragmatic approach prioritises feasible interventions such as early identification and treatment of anaemia, minimisation of avoidable blood loss, careful surgical haemostasis, and physiology-guided transfusion decisions.

### **SUMMARY**

Paediatric PBM has historically lagged behind adult practice and remains an understudied and under prioritised area of perioperative care. Addressing key evidence gaps will require development of paediatric-specific PBM algorithms and consensus guidance supported by clinical trials that reflect the physiological diversity of children. Emerging technologies may support physiology-guided transfusion decisions but require validation in paediatric populations. Moving from a “forgotten population” to one that is truly prioritised will require strengthening paediatric blood management through pragmatic context-appropriate PBM pathways involving coordinated multidisciplinary collaboration across diverse global healthcare settings.

## REFERENCES

1. Goobie SM, Faraoni D. Perioperative paediatric patient blood management: a narrative review. *Br J Anaesth*. 2025;**134**(1):168-179.
2. World Health Organisation. Guidance on implementing patient blood management to improve global blood health. Geneva, Switzerland: World Health Organisation; 2025.
3. Okur Acar S, Tüfekçi Gürocak Ö. Patient blood management in pediatric patients: current strategies and future perspectives. *Turk J Hematol*. 2025;**42**(3):170-180.
4. Murto K, Downey L, Goobie SM. Pediatric patient blood management: unique considerations. *ASA Monitor*. 2025;**89**(6):15-16.
5. GBD 2021 Anaemia Collaborators: Prevalence, years lived with disability, and trends in anaemia burden by severity and cause, 1990–2021: findings from the Global Burden of Disease Study 2021. *Lancet Haematol*. 2023 Jul 31;**10**(9):e713-e734.
6. World Health Organization. Health Topic. Anemia. Geneva: World Health Organization; 2016. Available from: [https://www.who.int/health-topics/anaemia#tab=tab\\_1](https://www.who.int/health-topics/anaemia#tab=tab_1). Accessed September 11, 2021.
7. Meyer HM, Torborg A, Cronje L, et al. The association between preoperative anaemia and postoperative morbidity in paediatric surgical patients: a secondary analysis of a prospective observational cohort study. *Paediatr Anaesth*. 2020;**30**:759-765.
8. Shander A, Corwin HL, Meier J, et al. Recommendations from the International Consensus Conference on Anaemia Management in Surgical Patients (ICCAMS). *Ann Surg*. 2023;**277**:581-590.
9. Brehm R, South A, George EC. Use of point-of-care haemoglobin tests to diagnose anaemia in low- and middle-income countries: a systematic review. *Trop Med Int Health*. 2023;**29**(2):73-87.
10. Neogi SB, Sharma J, Pandey S, et al. Diagnostic accuracy of point-of-care devices for detection of anaemia in community settings in India. *BMC Health Serv Res*. 2020;**20**:468.
11. World Health Organization. WHO guideline on haemoglobin concentrations for the diagnosis of anaemia and assessment of severity. Geneva: WHO; 2024.
12. WHO Guideline on Use of Ferritin Concentrations to Assess Iron Status in Individuals and Populations. Geneva: World Health Organization; 2020.
13. Zuluaga M, Galindo Zuluaga S, Goobie SM. Perioperative patient blood management: a new standard of care for pediatric patients. *Rev Chil Anest*. 2025;**54**(5):632-644.
14. Hassan N, Boville B, Reischmann D, Ndika A, Sterken D, Kovey K. Intravenous ferumoxytol in pediatric patients with iron deficiency anemia: a single-center experience. *Ann Pharmacother*. 2017;**51**:842-848.
15. Franchini M, Marano G, Veropalumbo E, Masiello F, Pati I, Candura F, Profili S, Catalano L, Piccinini V, Pupella S, Vaglio S, Liunbruno GM. Patient blood management: a revolutionary approach to transfusion medicine. *Blood Transfus*. 2019;**17**(3):191-195.
16. Brooke A, Krbec, Xiang Zhang, Inbar Chityat, et al. Emerging innovations in neonatal monitoring: a comprehensive review of progress and potential for non-contact technologies. *Front Pediatr*. 2024 Oct 14;**12**:1442753.
17. Balegar V, Low GK, Nanan RK. Regional tissue oxygenation and conventional indicators of red blood cell transfusion in anemic preterm infants. *EClinicalMedicine*. 2022;**46**:101365.
18. Liu L, Qiang Z, Zhang J, et al. Effect of hemoglobin content on cerebral oxygen saturation during surgery for scoliosis in pediatric patients. *BMC Anesthesiol*. 2021;**21**:165.
19. Booth EA, Dukatz C, Ausman J, Wider M. Cerebral and somatic venous oximetry in adults and infants. *Surg Neurol Int*. 2010 Nov 27;**1**:75.
20. Jaiswal N, Robinson W, Ciminata G et al. (2025) At what levels of expected blood loss from surgery is tranexamic acid (TXA) effective at reducing the need for blood transfusion?. MedRxiv preprint. doi:10.1101/2025.07.21.25331903
21. Goobie SM, Zurakowski D, Glotzbecker MP, et al. Tranexamic acid is efficacious at decreasing the rate of blood loss in adolescent scoliosis surgery: a randomized placebo-controlled trial. *J Bone Joint Surg Am*. 2018;**100**:2024-2032.
22. Barile L, Fominskiy E, Di Tomasso N, Alpizar Castro LE, Landoni G, De Luca M, Bignami E, Sala A, Zangrillo A, Monaco F. Acute normovolemic hemodilution reduces allogeneic red blood cell transfusion in cardiac surgery: a systematic review and meta-analysis of randomized trials [review]. *Anesth Analg* 2017; **124**:743-52.
23. Perez-Ferrer A, Gredilla-Diaz E, de Vincente-Sanchez J, Sanchez Perez-Grueso F, Gilsanz-Rodriguez F. Implementation of a patient blood management program in pediatric scoliosis surgery. *Rev Esp Anestesiol Reanim* 2016; **63**:69-77.
24. Crescini WM, Muralidaran A, Shen I, LeBlanc A, You J, Giacomuzzi C, Treggiari MM. The use of acute normovolemic hemodilution in paediatric cardiac surgery. *Acta Anaesthesiologica Scandinavica*, 04 Mar 2018, **62**(6):756-764.
25. Klein A. A., Bailey C. R., Charlton A. J., Evans E., Guckian-Fisher M., McCrossan R., Nimmo A. F., Payne S., Shreeve K., Smith J. and Torella F. Association of Anaesthetists guidelines: cell salvage for peri-operative blood conservation 2018. *Anaesthesia* 2018, **73**:1141-1150.
26. Ashworth A, Klein AA. Cell salvage as part of a blood conservation strategy in anaesthesia. *Br J Anaesth*. 2010;**105**:401-416.
27. Shander A, Kaplan LJ, Harris MT, et al. Topical hemostatic therapy in surgery: bridging the knowledge and practice gap. *J Am Coll Surg*. 2014;**219**:570-579.e4.
28. Ishikura H, Nishiwaki T, Fujita S, et al. Oxidized regenerated cellulose powder reduces perioperative bleeding and thigh swelling in total hip arthroplasty: a prospective interventional study. *J Orthop Surg Res*. 2025;**20**:505.
29. Lacroix J, Hébert PC, Hutchison JS, et al; TRIPICU Investigators; Canadian Critical Care Trials Group; Pediatric Acute Lung Injury and Sepsis Investigators Network. Transfusion strategies for patients in pediatric intensive care units. *N Engl J Med*. 2007; **356**:1609-1619.
30. Faraoni D, Meier J, New HV, Van der Linden PJ, Hunt BJ. Patient blood management for neonates and children undergoing cardiac surgery: 2019 NATA Guidelines. *J Cardiothorac Vasc Anesth*. 2019;**33**:3249-3263.
31. Haas T, Spielmann N, Restin T, et al. Higher fibrinogen concentrations for reduction of transfusion requirements during major paediatric surgery. *Br J Anaesth*. 2015;**115**:234-243.
32. Kietaibl S, Ahmed A, Afshari A, et al. Management of severe peri-operative bleeding: guidelines from the European Society of Anaesthesiology and Intensive Care: second update 2022. *Eur J Anaesthesiol*. 2023;**40**:226-304.
33. Kirpalani H, Bell EF, Hintz SR, et al. Higher or lower hemoglobin transfusion thresholds for preterm infants. *N Engl J Med* 2020;**383**:2639-51.
34. Franz AR, Engel C, Bassler D, et al. Effects of liberal vs restrictive transfusion thresholds on survival and neurocognitive outcomes in extremely low-birth-weight infants. *JAMA* 2020;**324**:560-70.
35. Valentine SL, Bembea MM, Muszynski JA, et al. Consensus recommendations for RBC transfusion practice in critically ill children from the Pediatric Critical Care Transfusion and Anemia Expertise Initiative (TAXI). *Pediatr Crit Care Med* 2018;**19**:S98-113.