Surgical decision making around paediatric preoperative anaemia in low-income and middle-income countries

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Prevalence of anaemia is high among children in low-income and middle-income countries. Anaemia is an important factor to consider preoperatively as low haemoglobin concentrations can have a negative effect on surgical outcomes and can also lead to surgeries being cancelled or postponed, which can have adverse health implications and stretch already limited resources in these countries. Additionally, blood transfusions to correct anaemia exposes children to safety issues. Therefore, where anaemia is known to be prevalent and resources are scarce, a contextually appropriate and relatively safe minimum haemoglobin concentration for proceeding to surgery could substantially improve patient management and efficiency of the health system. In this Review, we consider why paediatric anaemia is a major public health issue in low-income and middle-income countries, the value of preoperative testing of anaemia, and methods of optimising haemoglobin concentrations in the context of paediatric surgeries taking place in resource-limited settings.

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Introduction

In 2004, WHO and UNICEF released a statement that highlighted the widespread public health issue of anaemia in children and its effect on physical and cognitive development.[1] Studies from the past decade and recent estimates from WHO have shown a high prevalence of paediatric anaemia, with more than 70% of children affected in developing countries in sub-Saharan Africa and southeast Asia.[2–4] These estimates do not always provide an accurate reflection of the true prevalence of anaemia, which could be higher, because they are based on surveys and inconsistencies in participation, coverage, and data analysis often exist. However, studies consistently show that anaemia has a substantially higher prevalence in low-income and middle-income countries (LMICs) than in high-income countries, and one study[5] showed that children younger than 5 years have the highest severity of anaemia in these settings.

Causes of anaemia

The high prevalence of paediatric anaemia in LMICs can be attributed to many causes, such as malnutrition, parasitic infections, haemoglobinopathies, and HIV and AIDS. Anaemia caused by iron deficiency is thought to be the most common cause in all age groups worldwide and can occur because of low dietary intake, increased demands with growth and pregnancy, blood loss resulting from heavy menstrual bleeding, and parasitic infections such as hookworm infections and schistosomiasis. Anaemia can also occur because of poor nutrition and a deficiency of micronutrients (eg, vitamin A and riboflavin).[6] In endemic countries, malaria has been shown to be an important cause of anaemia.[7]

Haemoglobinopathies are of particular importance in LMICs, with 80% of children born each year with this condition.[8] Additionally, there is low availability of screening programmes for newborns for haemoglobinopathies in resource-limited environments,[9] and many cases could go undetected until later in childhood. These causes are predominantly faced in LMICs and can collectively contribute to anaemia. Therefore, care must be taken in assessment before surgery in relevant geographical areas and populations, especially if access to oxygen is restricted.

Various socioeconomic factors, including poverty, antenatal care, provision of iron supplementation in pregnancy, maternal diet in pregnancy, familial level of education, poor preventive measures for malaria, and rural location contribute to the high prevalence of anaemia in children in LMICs.[10–13] A study in India,[14] one of the countries with the highest prevalence of paediatric anaemia, showed that the socioeconomic factors associated with a caste-based system correlated with the anaemic status of children. The caste-based system has contributed to disparities in health outcomes because of differences in access to health care and education, financial means, and social discrimination. A

Key messages

- Paediatric anaemia is a substantial issue in low-income and middle-income countries, with haemoglobinopathies, parasitic infections, and socioeconomic factors being important contributors.
- The effect of preoperative anaemia on surgical outcomes in children is substantial.
- Preoperative anaemia testing in resource-limited settings should be reserved for children at high risk (eg, in areas with high prevalence of haemoglobinopathies and malaria, patients undergoing major surgeries, and patients with serious comorbidities).
- Blood transfusion is not a treatment for anaemia; however, when warranted, a restrictive approach reduces associated costs and risks of transmitted infections.
- Strategies for patient blood management in children, such as iron supplementation and tranexamic acid, has the potential to substantially improve the clinical and economic burden of paediatric anaemia in the context of surgery in low-income and middle-income countries.

study[15] highlighted that social discrimination due to the caste system was a main cause of increased paediatric anaemia even after adjusting for economic factors.

Importantly, a study by Yang and colleagues[16] was the first to empirically show the extent of socioeconomic inequalities in LMICs on the prevalence of paediatric anaemia and how these inequalities hinder treatment and prevention efforts. Their cross-sectional analysis of 163 419 children aged 6–59 months from 45 LMICs showed that anaemia was present in at least 40% of children in 24 of the 45 countries. Among 24 LMICs that had repeated cross-sectional data sets, some decrease in anaemia prevalence was seen between 2000 and 2014; however, the socioeconomic inequalities in relation to anaemia did not fall in those countries where this decrease in anaemia was seen.

Preoperative anaemia and surgical outcomes

Children younger than 5 years are especially susceptible to the long-term effects of anaemia, which is particularly important to consider perioperatively. Optimal management of perioperative anaemia can be challenging to implement in many LMICs because of limited resources. Appropriate, formalised strategies might be in short supply to detect the condition. Therefore, careful consideration of the implications of anaemia on postoperative complications is required to make management decisions that are clinically and economically effective.

Studies in both high-income countries and LMICs that examine the effect of preoperative anaemia in children are scarce. A study by Faraoni and colleagues[17] used a national American paediatric database and found that 74 508 (41%) of the 183 833 children studied had recorded preoperative haematocrit values. After excluding children younger than 1 year and children who received transfusion preoperatively or had congenital heart disease, preoperative anaemia was present in 24% of children and was significantly associated with increased risk of in-hospital mortality after adjusting for comorbidities.

Similarly, a study by Fontanals and colleagues[18] looked at a cohort of 9095 children undergoing spine arthrodesis surgery, of whom 1233 (14%) had preoperative anaemia. The condition was associated with prolonged hospital stay and increased need for blood transfusion; however, pretransfusion and post-transfusion haemoglobin concentrations were not investigated. This study highlights the need for management strategies for preoperative anaemia because timely detection and intervention, especially in the context of elective surgery, can theoretically reduce the need for transfusions in LMICs because of the associated safety and access-related issues.

A large multicentre, database analysis based in the USA[19] showed an independent association between preoperative anaemia and postoperative in-hospital mortality in neonates undergoing non-cardiac surgery even after controlling for physical status (American Society of Anesthesiologists [ASA] class), bodyweight, pre-operative inotropic support, or preoperative mechanical ventilation.

However, when taking such statistics into account, consideration of the population being studied is important. The expectation is that preoperative anaemia will be easier to manage in high-income countries than in LMICs because of the availability of resources. In LMICs, widespread malnutrition and parasitic infection add to the burden of anaemia and inadequate resources increase difficulty in effective management, which can potentially contribute to poorer outcomes in children in these countries.

By contrast, one study[20] showed that preoperative anaemia was not significantly associated with increased postoperative complications for children. However, compared with the previous studies, this study is relatively small, with 110 children undergoing resection of primary liver tumours and a large proportion (69%) with preoperative anaemia.

Moreover, the importance of preoperative anaemia on surgical outcomes is also reiterated in adult populations. Musallam and colleagues[21] used a validated outcomes registry from 211 hospitals worldwide to investigate the effect of preoperative anaemia in patients undergoing non-cardiac surgery. 69 229 (30%) of 227 425 patients (mean age 56·4 years; range 16–90) in this study had preoperative anaemia; regardless of severity, preoperative anaemia was an independent risk factor for increased 30-day mortality and morbidity for all age groups, sexes, and surgical specialties.

Baron and colleagues[22] did a prospective study that highlighted the implications of preoperative anaemia in 39 309 adults in 28 European countries, of whom 31·1% of men and 26·5% of women were anaemic. After adjusting for patient comorbiditiy and urgency of surgery, the study showed that moderate and severe anaemia as defined by WHO criteria was associated with increased in-hospital mortality, with severe anaemia carrying an even greater risk. Increased length of hospital stay and greater use of intensive care unit (ICU) resources were overall significantly greater in patients with preoperative anaemia than in those with normal haemoglobin concentrations. Similarly, a study[23] in Ghana of 893 inpatients aged at least 15 years, of whom 54% had preoperative anaemia, showed a strong association between the condition in non-cardiac surgery and an increased length of hospital stay.

Well-established evidence shows that preoperative anaemia in adult cardiac surgery is independently associated with worse outcomes.[24,25] A meta-analysis[26] assessing the effect of preoperative anaemia on post-operative outcomes showed that significant associations with increased mortality, acute kidney injury, and infection. However, the study was not able to distinguish whether the poor outcomes were related to anaemia or the underlying comorbidities because of the heterogeneity of studies included.

Although paediatric studies on preoperative anaemia are scarce, preoperative anaemia has been consistently highlighted, among different patient demographics, as an important independent determinant of post-surgical outcomes.

Considerations for preoperative anaemia screening

Most studies on preoperative anaemia screening have been done in high-income countries, and the high prevalence of the condition could be caused by clinical comorbidities because these studies focused on major surgery. However, an international cohort study[27] involving adults undergoing elective surgery in 27 countries showed that the prevalence of preoperative anaemia was slightly higher in LMICs than in high-income countries (32·5% *vs* 28·5%), even though the patients from LMICs were younger and had a lower ASA grade status (ie, physically fitter). This finding could be due to underlying differences in causes such as malnutrition in LMICs versus cancer or chronic disease in high-income countries. In this cohort, patients from LMICs with preoperative anaemia had similar mortality rates but increased postoperative complications compared with those from high-income countries. These findings raise the question of whether the differences in outcome are due to management strategies in LMICs or differences in the underlying causes of anaemia.

By contrast, a study[28] in Nigeria showed a low prevalence of anaemia (2·6%) among adults attending day surgery and argued that preoperative testing should be carried out depending on the clinical picture, type of procedure, and patient profile. Similarly, a systematic review[29] showed that the prevalence of preoperative anaemia varies from 5% in older women presenting with hip fracture to 76% in patients with advanced colon cancer. The study highlights that these differences could be attributed to the specific cut-off value of haemoglobin concentration used and variation in patient population—from young and healthy individuals to patients with chronic conditions, or gynaecological cases where bleeding itself is usually the presenting problem or indication for surgery.

The high incidence of paediatric anaemia in LMICs makes it probable that the disease burden is substantial, particularly with the collective effect of the premorbid conditions that require surgery. Preoperative anaemia, especially in severe cases, undoubtedly has a negative effect on surgical outcomes; however, the usefulness of routine screening in LMICs is also important to consider. There might not be adequate management strategies in place to correct anaemia in LMICs, which could lead to inappropriate delays in surgery and could potentially worsen patient outcomes.

A study[30] on routine preoperative testing in 201 adults undergoing non-urgent surgery in Côte d'Ivoire found that although 29% had anaemia and 10% had severe anaemia, change in management only occurred in 1·7% of cases. However, the diagnosis of anaemia was given as the reason for 5·1% of surgeries being delayed. In this study, the type of procedures included orthopaedics, visceral, and gynaecological surgeries, but the proportion of these surgeries that carried a high bleeding risk was not indicated. One of the biggest limitations of this study was that postoperative follow-up was not done. Assessment of whether there was a higher postoperative morbidity in cases where diagnosis of anaemia was made but management was not changed would be interesting.

A multicentre study, in four Spanish hospitals,[31] assessing the value of routine preoperative testing in 3131 patients at low risk of anaemia had similar findings. This study excluded adult and paediatric patients with an ASA grade of greater than two and patients undergoing emergency procedures. Only 3% of patients had unexpected haematological abnormalities including anaemia, and white blood cell and platelet abnormalities. Subsequent management was altered in only 0·26% of the cases. Other studies have also questioned the value of screening with laboratory tests, including haemoglobin concentrations, in cases where there is little clinical effect.[32–34]

Routine screening for preoperative anaemia, especially in a resource-limited setting, might not always activate the necessary action. Moreover, in healthy individuals, routine testing of preoperative haemoglobin concentrations is not shown to substantially affect treatment management. In the UK, as per guidelines of the National Institute for Health and Care Excellence,[35] routine full blood count testing for any patient having minor surgery or with ASA grade of one or two having intermediate surgery is not recommended; instead, anaemia is only tested in these patients if they have specific indications.

By this principle, preoperative anaemia testing should be reserved for patients with specific comorbidities, undergoing major surgery with high bleeding risk, or are at a higher risk of being anaemic—for example, children who are malnourished or live in areas where malaria or parasitic infections are common. Similarly, in LMICs where haemoglobinopathies are endemic, preoperative anaemia testing should be done, especially where anticipated blood loss could worsen the anaemia. Identification of children at high risk can enable timely intervention such as iron supplementation in elective surgery, thereby reducing the need for perioperative transfusion. However, in children with severe haemoglobinopathies who are undergoing major surgery, preoperative transfusion might be beneficial in selected cases after careful consideration of comorbidities and potential complications.

Assessing preoperative haemoglobin concentrations

In individuals with clinically significant anaemia who warrant treatment, it is important to determine what can be considered a safe haemoglobin concentration in relation to the type of surgery and whether they are likely to have adequate physiological compensation and therefore tolerate blood loss from surgery. To our knowledge, there are no guidelines that suggest a haemoglobin concentration below which anaemia would have to be treated before proceeding to surgery, such as by postponing non-urgent or emergency procedures to treat anaemia, or transfusing patients to optimise haemoglobin concentrations before time-bound procedures. Routine preoperative transfusion is not recommended; however, in certain situations the risks and benefits must be considered. For Wilms' tumour, the standard treatment protocol is for surgery to happen at week 6 after chemotherapy; if haemoglobin concentration is low, then transfusion can be considered to facilitate surgery.

Existing literature regarding the safe concentration of preoperative haemoglobin are usually in the context of transfusion. Studies have shown that restrictive transfusion can facilitate safe surgery. For example, a case-control study[36] of 125 adults who declined blood transfusion because of religious reasons found an inversely proportional relationship between mortality and preoperative haemoglobin concentration, with a mortality rate of up to 62% for patients with concentrations below 6 g/dL. Interestingly, no patients with a haemoglobin concentration above 8 g/dL and blood loss below 500 mL died, which suggests that safe surgery might be facilitated with lower haemoglobin concentrations when stratified according to bleeding risk.

A Cochrane review[37] of 19 trials involving 6264 patients, including children, supported the use of restrictive transfusion (indicated most commonly at 7 g/dL or 8 g/dL) and showed that a restrictive strategy had no effect on 30-day mortality or morbidity when compared with those receiving a liberal transfusion strategy (most commonly 9–10 g/dL). Discussion of paediatric transfusion is discussed later. However, we would like to highlight that there is a scarcity of evidence to guide surgical decision making in the context of preoperative anaemia. Furthermore, even if a preoperative, safe minimum haemoglobin concentration is identified, a strict arbitrary threshold might not have an effect on postoperative complications, especially in low-risk procedures. For example, a study[38] of 2064 adults and children undergoing elective surgery in the Republic of the Congo and Madagascar stratified patients by anaemia severity, as per WHO guidelines, and showed that although severe anaemia was associated with unplanned ICU admission, surgical site infection, and hospital readmission, mild anaemia was not significantly associated with postoperative complications.

Similarly, a two-part study[39] consisting of 452 patients based in India carried out a retrospective chart analysis on anaemia and postoperative complications, as well as a prospective analysis of the effect of appropriate management of preoperative anaemia on postoperative complications. Both parts of the study showed that preoperative anaemia was not significantly associated with postoperative complications and that the incidence of complications did not increase with severity of anaemia. By contrast, studies done in high-income countries have shown that even mild anaemia is an independent risk factor for postoperative morbidity or complications.[21,40]

This difference could be due to the relatively low risk of bleeding in procedures such as hernia repair that were included in the studies done in LMICs. Another reason could be apparent physiological compensation of anaemia (such as increased cardiac output) in LMICs where causes of anaemia are endemic, or perhaps because the population in the studies from LMICs were younger.

These studies highlight that the assessment of preoperative safe minimum haemoglobin concentration should be done in the context of the clinical situation, considering patient comorbidities, as well as the urgency and anticipated blood loss of the procedure. For example, a non-urgent procedure with a high risk of bleeding can be delayed. More accessible and safer methods, such as iron supplementation, might be suitable in LMICs where transfusion might be unsafe and can be prioritised for patients requiring urgent surgery where there is a shortage of blood supply. A multidisciplinary team setup would be required for choosing the most appropriate method of haemoglobin correction as dictated by safety, availability of resources, and clinical urgency of the procedure.

Management of perioperative anaemia in LMICs

In high-income countries, policies for patient blood management have revolutionised anaemia management perioperatively. Patient blood management refers to the optimisation of haemoglobin concentrations through various strategies, such as transfusion, minimising blood loss associated with surgery, and optimising tolerance to blood loss after surgery. This strategy is achieved through joint input from various professionals within a multidisciplinary team. Of note, strategies for patient blood management focus on optimising haemoglobin concentrations rather than being treatments for anaemia (eg, transfusion) and should be carried out in a patient-centered approach in which the most appropriate methods of optimising haemoglobin concentration are chosen in accordance with the clinical context and the patient's wishes.[41,42]

Although several adult blood management guidelines exist, they are not immediately transferable to the paediatric population. For example, adult guidelines recommend a specific pathway for surgeries where blood loss is expected to be greater than 500 ml,[42] which is not applicable for children in whom there is substantial variation of blood volumes. Guidelines also exist for target haemoglobin concentrations that are again not transferable to the paediatric population because of the variation of haemoglobin concentration range and oxygen requirements among different age groups.

Strategies for patient blood management that are specific to the paediatric population have been discussed previously,[43] and we will focus on aspects of patient blood management in resource-limited settings and how it can influence surgical decision making.

Preoperative blood management

Large-scale public health initiatives led by WHO, and national and local programmes, such as deworming, malaria prevention, and the fortification of common food items with iron, can substantially help to reduce the burden of anaemia in LMICs.[44] Before surgery, adequate communication between all teams involved in patient care is an essential part of preoperative blood management. Similarly, universal tools such as the WHO surgical checklist is paramount in anticipating complications and promoting techniques to minimise operative blood loss (figure).

Preoperative planning is an essential form of patient blood management in LMICs and is not only limited to optimising haemoglobin concentrations but also a consideration of access to supplemental oxygen to avoid catastrophic hypoxic events in patients with anaemia. Of a variety of preoperative strategies, we have identified two key aspects in relation to LMICs: iron supplementation and restrictive transfusion.

Iron supplementation before surgery, and in particular parenteral iron, has been shown to be beneficial in adults.[42,45,46] One paediatric spinal study[47] also showed that intravenous iron was comparatively better than oral iron supplementation in correcting iron deficiency anaemia. However, the overall evidence regarding oral supplementation is not well studied in children.[48] Although iron supplementation might not be suitable as the main form of haemoglobin correction preoperatively, when planned and carried out in advance after considering individual risks of overload and urgency of the surgical procedure, this method is safe and cost-efficient for blood management.

The British Committee for Standards in Haematology guideline on transfusion in neonates and older children (up to 18 years) advises optimising preoperative haemoglobin concentrations by treating iron deficiency anaemia before elective surgery, especially where there is a high risk of blood loss.[49] This method can also be used in the postoperative period to correct anaemia.

Although transfusion is not a treatment for anaemia, this intervention is necessary to correct haemoglobin concentrations in selected cases (eg, before an urgent surgical procedure when substantial blood loss is anticipated). When applicable, a restrictive strategy should be sought because risks are not only limited to infection but also include potentially fatal risks, such as transfusion-related acute lung injury, transfusion-related circulatory overload, immune-related reactions, bacterial contamination, and human errors (eg, transfusing the wrong blood type or overloading).

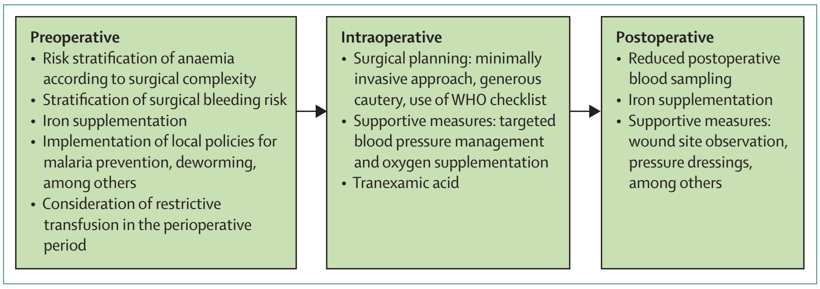

Figure: **Patient blood management strategies relevant to low-income and middle-income countries**

Several randomised controlled trials and a Cochrane review have all shown the benefit of restrictive transfusion in adults.[37,50–52] In paediatrics, the landmark TRIPICU trial[53] and its substudies compared a restrictive threshold of 7 g/dL with a liberal threshold of 9·5 g/dL in children who were stable but critically ill, and found restrictive transfusion to be superior in the paediatric population. However, these findings should be interpreted with caution in patients with cardiac abnormalities or haemodynamic instability because these patients might not have the physiological reserve to tolerate low haemoglobin concentrations.

A systematic review[54] focusing on studies in high-income countries concluded that a haemoglobin concentration of 6·93 g/dL for children admitted to the paediatric ICU with burns, sepsis, or after general and cardiac surgery is safe. The safety outcomes measured were proportions of new or progressive multiorgan dysfunction syndrome, mortality, nosocomial infections, transfusion reactions, length of ventilation, and length of ICU stay. The review also found that 9·02 g/dL can be safe for children with cyanotic heart disease. Using lower thresholds would be particularly beneficial in LMICs because the number of children receiving transfusion would be substantially reduced, thereby minimising the associated risks of incompatibility, reactions, and infections, as well as the cost associated with transfusion.[55]

The British Committee for Standards in Haematology recommends minimising the volumes of transfusion in the absence of strong evidence to suggest the contrary. They also support the use of 7 g/dL as a threshold for transfusion in children who are stable and do not have cyanotic heart disease and recommends a higher threshold might be considered for the children who do not fall into this category.[49]

Appropriate use of patient blood management techniques can substantially reduce the need for transfusion. In a cohort study[56] of 210 children who had similar characteristics and underwent the same surgical treatment for idiopathic scoliosis (which carries a risk of substantial blood loss), the use of strategies for patient blood management such as prophylactic tranexamic acid and permissive intraoperative hypotension, in conjunction with a restrictive transfusion approach, led to a decline in intraoperative transfusion from 77% to 13% over 5 years. This study used restrictive thresholds of less than 7·3 g/dL from 2011 to 2013 and less than 7·0 g/dL from 2014, as per national Danish protocols at the time.

Hence, transfusion itself should not be the mainstay of anaemia management preoperatively and, when warranted, should be used judiciously with other aspects of patient blood management.

Intraoperative patient blood management

Several intraoperative methods can be used to minimise blood loss. Surgical techniques include generous cautery, minimally invasive approach, use of a tourniquet where appropriate, and careful planning in relation to vascular anatomy (figure). Furthermore, positioning patients to reduce venous engorgement should be actively discussed in the planning phase of patient care where risk of haemorrhage is moderate or high. Discussions with anaesthetists regarding the role of permissive hypotension, and use of vasoconstrictors and antifibrinolytics also have a role in reducing the burden of blood loss.

Trials in the context of adult trauma (CRASH II)[57] and post-partum haemorrhage (WOMAN)[58] have provided robust evidence to support the life-saving and cost-effective value of tranexamic acid, particularly in LMICs. Strong evidence suggests that administration of tranexamic acid perioperatively can reduce blood loss and the need for transfusion in children.[59,60] The British Committee for Standards in Haematology recommends that tranexamic acid should be considered in all children undergoing surgery where there is a risk of substantial bleeding. This method could be a relatively safer, simpler, and cost-efficient approach for patient blood management in comparison to transfusion and would be invaluable in LMICs where other facilities are not well established.[49] Although we could not find specific data on the accessibility of tranexamic acid in LMICs, this drug is relatively inexpensive and is one of the core items on the WHO model list of essential medicines that is used by many LMICs to guide local medicines supply. A study[61] based on data from patients undergoing surgery in four sub-Saharan African countries used a cost-analysis model that showed tranexamic acid to be highly cost-effective in the treatment of bleeding in elective surgical patients, and to potentially reduce mortality in settings where transfusion services are limited.

Cell salvage and subsequent reinfusion is a robust technique that is considered relatively safe. It does not carry the same risk of incompatibility and infection as allogenic transfusion, and is safer than unnecessary autologous donation. Studies have shown that cell salvage could reduce the need for transfusion in children undergoing major surgery.[62–65] The British Committee for Standards in Haematology guidelines recommend that red cell salvage should be considered in all children at risk of substantial bleeding who are undergoing surgery and where transfusion might be required, provided trained staff are present.[49]

However, cell salvage is not available in all countries. In LMICs, the feasibility of this method can be challenging, especially if no strict criteria exist for collection and storage of blood. The requirement of additional training for staff and cost of equipment, especially for low-volume cell salvage systems for children, challenge the implementation of this strategy as a routine method of patient blood management. Furthermore, in countries where haemoglobinopathies such as sickle cell anaemia is common, cell salvage is not advisable. The Association of Anaesthetists of Great Britain and Ireland advises a case by case consideration for the use of cell salvage in patients with malignancy or in surgery involving infected fields because of theoretical risks such as metastasis following re-infusion and worsening sepsis.[66]

Postoperative blood management

Reduced, guideline-led postoperative blood sampling has a role in minimising the effect of anaemia postoperatively. A study[67] of 319 children who underwent cardiac surgery in the USA showed that controlled ordering of blood tests postoperatively, as dictated by the clinical need, compared with standardised postoperative blood sampling, had a significant reduction in the number of total blood tests per patient and and the number of tests had by individual patients per day (after adjusting for length of hospital stay). Reduced sampling was also shown to be more cost-efficient and no significant difference was shown in adverse outcomes (eg, extubation failure, hospital mortality, and central-catheter-associated infection). Reduced postoperative blood sampling is particularly relevant to patients undergoing minor procedures in LMICs, where laboratory resources could be directed as per clinical need. Other supportive postoperative measures of patient blood management include wound site observations, use of pressure dressings, and reduced dressing changes, where clinically appropriate.

Conclusion

Ultimately, a combination of techniques should be used in relation with the clinical context to determine the best way of managing the implications of anaemia on surgical outcomes. Although transfusion is an important part of patient blood management, this intervention should be used carefully. Particularly in LMICs, the use of other patient blood management techniques (figure) can substantially reduce the risks associated with transfusion, improving health and economic outcomes. It is important to identify children at risk of developing adverse outcomes associated with

Search strategy and selection criteria

Data for this review were identified by searches of PubMed, Ovid, Google Scholar, the WHO website, and references from relevant articles using the search terms “paediatric anaemia in low and middle income countries”, “socioeconomic factors and anaemia”, “preoperative anaemia and surgical outcomes”, “preoperative anaemia screening”, “haemoglobin thresholds for surgery”, and “patient blood management”. Articles published in English between January 2000 and February 2019 were used for the original search criteria. References from relevant articles from the original selected papers and suggested papers from peer review were also included.

preoperative anaemia, and appropriate patient blood management strategies should be incorporated within surgical decision making.

Contributors

KL and JT planned the manuscript, SC and SED performed the literature search. All authors contributed to the manuscript.

Declaration of interests

We declare no competing interests.

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