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Perioperative Blood Management Strategies in Anemic Patients Undergoing Surgery: A Narrative Review

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Abstract

Perioperative anemia is a common occurrence in patients undergoing surgery. The severity and cause of anemia can vary in different clinical settings. Anemia can complicate surgical patients and adversely affect the recovery of these individuals after surgery. Some of the causes of perioperative anemia include microcytic anemia and acute blood loss due to gastrointestinal bleeding or trauma. Other causes include hemodilution after fluid resuscitation and physiological changes in pregnancy. Managing anemia in surgical patients is an important aspect of perioperative care. In this narrative review, the causes of perioperative anemia, its consequences, and the effects of anemia on postoperative care were examined. Two independent reviewers conducted a literature search for studies related to perioperative anemia. The studies reviewed were published between March 27th, 1997, and April 14th, 2026. The literature search included the terms "perioperative anemia," "preoperative anemia," "postoperative anemia causes," and "anemia in elective surgeries." Perioperative anemia is a problem in both elective and emergency surgeries. It may remain a problem for patients during the postoperative period. Identifying and correcting the causes of anemia before surgery is an important part of clinical practice. However, several confounding factors may influence the development and persistence of anemia in surgical patients.

Categories: Family/General Practice, General Surgery, Anesthesiology
Keywords: intravenous iron, iron deficiency, patient blood management, preoperative anemia, transfusion thresholds

Introduction And Background

Perioperative anemia is defined by the WHO as having a hemoglobin level below 13 g/dL for men and below 12 g/dL for women. Approximately 30% to 40% of patients undergoing surgery present with anemia. Various guidelines suggest that the perioperative hemoglobin level for patients of both sexes should be above 13 g/dL. Anemia is common in older adults with conditions like chronic kidney disease, malignancy, and chronic inflammatory diseases. Anemia is often under-recognized and considered clinically insignificant in the perioperative setting [1,2].

Studies have challenged the belief that anemia is insignificant in the perioperative setting. Musallam et al. [1] and Baron et al. in a study of 39,000 surgical patients [3] found that patients with mild anemia perioperatively have an increased risk of morbidity and mortality. Anemia causes a reduction in the oxygen-carrying capacity of the blood, and patients may require a blood transfusion, which increases the risks for the patient. Anemia is associated with an increased risk of infection, altered immune function, and mortality [4-7].

Anemia in surgery can result from a variety of causes. Nutritional deficiencies, chronic blood loss, and impaired absorption of nutrients are all contributors to anemia. Iron deficiency is the most common cause of anemia worldwide [8]. Other causes of anemia include chronic disease and inflammation. The inflammatory process in the body increases the production of hepcidin, a hormone that regulates the availability of iron in the body. This increase in hepcidin reduces the availability of iron in the body, leading to functional iron deficiency [9,10]. Additionally, the inflammatory process increases the level of ferritin in the body. Ferritin is a protein that stores iron in the body. High levels of ferritin in the blood can make it difficult to diagnose iron deficiency.

Surgical stress can worsen anemia. The inflammatory response following surgery increases the level of inflammation in the body. Inflammation also causes changes in the distribution of fluids in the body and the metabolism of iron. In addition, the loss of blood during surgery increases the burden on the patient's body. If the patient's hemoglobin level is already reduced prior to surgery, this increased burden of blood loss during surgery can contribute to anemia. Anemia can cause impaired oxygen delivery to the body. This

impairment in oxygen delivery can delay the patient's recovery from surgery, prolong hospitalization, and increase postoperative complications [11,12]

Historically, blood transfusion has been the go-to method of correcting low hemoglobin levels in patients going into surgery. However, subsequent evidence has demonstrated that liberal use of transfusions does not improve outcomes for patients and, in some cases, is associated with harm to the patients [13-15]. As a result, alternatives to transfusion have been developed, including correcting anemia before surgery, using intravenous iron, using erythropoiesis-stimulating agents (ESAs), and using more restrictive transfusion thresholds.

These alternatives to blood transfusions contributed to the development of patient blood management (PBM). Patient blood management is a model of care that seeks to identify and treat anemia in patients going into surgery and to minimize blood loss and the use of transfusions during surgery. Recommendations from the American Association of Blood Banks (AABB) in 2023 [16], the WHO in 2010 [17], and Muñoz et al. in 2017 [18] all support the use of PBM in the perioperative period. However, the implementation of PBM varies between healthcare settings.

Anemia is common in patients going into surgery, but many of the contributing factors to anemia in these patients can be identified and managed before surgery. Identifying these factors allows healthcare providers to improve the management of patients going into surgery and to reduce the complications that may occur during or after surgery. Consistent use of the strategies to manage anemia before or during surgery will help patients to recover from surgery and to reduce the number of interventions that are required after surgery.

Methods

This paper presents a narrative review of existing studies on perioperative anemia along with its management. A focused, though not systematic, literature scan was conducted using PubMed, MEDLINE/PMC, ScienceDirect, and Cochrane, using articles from 1997 to 2026. Search terms combined phrases such as "perioperative anemia," "postoperative anemia," "iron deficiency," "erythropoiesis-stimulating agents," and "patient blood management." Other related queries involved "iron supplementation," "intravenous iron," and "oral iron," plus concerns about restricted blood transfusions. In addition, reference sections of key articles were reviewed to ensure no critical studies were missed. The literature search was conducted independently by two authors, limited to English-language publications, and included a broad screening of relevant articles rather than a fixed inclusion count, consistent with a narrative review approach.

This review focuses on key clinical outcomes rather than listing every available study. Selected sources include randomized trials, observational data, systematic reviews, established protocols, as well as global recommendations used as core references. Inclusion and exclusion criteria were defined as follows: research involving adults undergoing surgery received priority in evaluation. Studies examining blood disorders, causes of low hemoglobin, iron treatment strategies, erythropoietin use, transfusion methods, or bleeding management defined the scope. Works centered on children, non-clinical analyses, case reports, or non-peer-reviewed opinions were excluded.

In line with narrative review methods, formal PRISMA steps were not used, nor was bias assessment included. Formal bias assessment was not undertaken due to the narrative nature of the review; however, credibility was supported through inclusion of peer-reviewed studies, use of established clinical guidelines, and independent evaluation of the literature by more than one author. Rather, the focus went toward solid clinical studies together with reliable guidelines, aiming to offer a clear and cohesive overview of perioperative management of anemia.

Review

Pathophysiology of perioperative anemia

The development of anemia prior to surgery may have several causes. Some of these causes are related to existing medical conditions prior to surgery, while others develop as a result of the surgical process itself. One of the most common causes of preoperative anemia is iron deficiency. Deficiency of iron may be caused by a lack of iron in the diet, excessive loss of blood from the gastrointestinal tract or menstruation, or the inability of the body to absorb iron. Functional iron deficiency is another form of anemia that is related to inflammation within the body that increases the level of hepcidin, which prevents the body from utilizing stored iron for the production of new red blood cells [8-10]. Both absolute and functional iron deficiencies are common in patients with surgical conditions like malignancy or chronic kidney disease.

Anemia of chronic disease

Inflammatory cytokines have the ability to suppress the production of red blood cells and reduce the availability of iron in the body. Such an effect can lead to the development of anemia in patients suffering from chronic conditions like cancer, heart failure, and arthritis. As detailed by Weiss et al. [9], even modest

increases in inflammation within the body can lead to the impairment of red blood cell production and pose a greater risk of perioperative complications for the patient.

Perioperative physiologic stress

Surgery can contribute to or worsen anemia through a number of mechanisms. Administration of intravenous fluids during surgery can cause hemodilution of the blood, lowering the hemoglobin concentration in the patient's blood. Blood loss during surgery also directly reduces the circulating number of red blood cells in the patient's blood, which can increase the physiologic stress on vital organs.

The inflammatory response to surgery also contributes to anemia. The cytokines released in response to surgery increase the production of hepcidin in the body, which reduces the availability of iron in the body and limits the production of red blood cells through erythropoiesis. Older adults and individuals with impaired renal function often have a reduced response to erythropoietin, which delays the recovery of red blood cell mass [11,12].

Together, these mechanisms contribute to the worsening of pre-existing anemia in patients undergoing surgery and can reduce the oxygen delivered to the vital organs of the body. The resulting tissue hypoxia increases the risk of complications following surgery. Recognizing these physiologic changes and managing them appropriately has the potential to improve the outcomes of patients undergoing surgery [11,12].

Impact on oxygen delivery and organ function

A lower level of hemoglobin within the blood will decrease the amount of oxygen that the blood can carry from the lungs to the rest of the body. The organs that require high levels of oxygen, such as the brain and the heart, are more likely to suffer damage as a result of a reduction in hemoglobin levels within the blood. According to Spahn and Goodnough [12], reduced levels of hemoglobin can further endanger patients with vascular diseases by increasing the risk of myocardial infarctions, arrhythmias, and strokes during the perioperative period.

Epidemiology and prevalence

Anemia is a common condition among preoperative patients and is associated with adverse surgical and postoperative outcomes. Global studies indicate that around 30 to 40% of patients presenting for surgery have anemia, with prevalence rates exceeding 50% in higher-risk populations undergoing procedures in orthopedics, gastrointestinal, cardiac, or oncologic specialties [1,2,19,20].

According to the WHO, iron deficiency is a major contributor to anemia worldwide. Women of reproductive age and older adults are more likely to be affected by anemia due to the demands placed on their bodies by menstruation, pregnancy, lactation, and chronic illnesses [2]. The failure to identify anemia in the preoperative period can lead to adverse outcomes after surgery, such as increased need for blood transfusions, delayed wound healing, infections, and others.

Musallam et al. conducted a study involving more than 227,000 patients. Their study revealed that approximately one-third of the patients had anemia before their surgeries. This group of patients had an approximately 40% higher risk of dying within 30 days of their surgeries [1]. Additionally, a study conducted by Baron et al. [3], involving 39,000 patients in Europe, revealed that even mild anemia was associated with increased risks of adverse outcomes, admission to intensive care units, and mortality.

Two studies conducted by Wu et al. and Xiao et al. revealed a U-shaped association between the preoperative hematocrit values of patients and their postoperative outcomes. Both low and high hematocrit values were associated with adverse postoperative outcomes. These findings indicate that while preoperative anemia should be addressed, care must be taken to avoid excessively correcting the hemoglobin levels of patients during their perioperative management period [21,22].

Further studies from North America and Europe confirm the findings of the studies discussed above. Preoperative anemia is prevalent among patients undergoing surgery and is associated with adverse postoperative outcomes [20,23]. Despite the existence of recommendations for the management of anemia before surgery, it remains underrecognized and often inadequately addressed.

Preoperative assessment and management

It is important to identify anemia before surgery so that it may be treated before the patient undergoes major elective surgery. Assessment of anemia should take place at the time that the surgery is being planned so that the treatment for anemia can be started as required [11,18]. Assessments should include a complete blood count and tests for iron deficiency. Other tests that may be required include ferritin, transferrin saturation, renal function, vitamin B12, and folate levels, in addition to investigation of ongoing blood loss based on the patient's clinical history [11,18].

Treatment for preoperative anemia should focus on addressing the cause of the anemia rather than the patient's hemoglobin level. For example, if the anemia is caused by iron deficiency, the patient's iron levels should be corrected prior to surgery. Oral iron treatments can be used when there is enough time to treat the anemia, but intravenous treatments should be used when time is limited, the patient cannot tolerate oral iron treatments, or when iron deficiency anemia is present prior to surgery [18].

Iron therapy

Oral Iron

Oral iron is appropriate in the days following the identification of iron deficiency and around six to eight weeks before surgery. Treatment usually involves the administration of 40 to 60 mg of elemental iron daily or 80 to 100 mg of elemental iron on alternate days [18]. Gastrointestinal adverse effects of oral iron supplementation may limit patient adherence to the treatment regimen [24,25]. When oral treatment is not tolerated by the patient, does not produce an adequate response, or when surgery is planned within six weeks of iron deficiency diagnosis, intravenous iron should be considered [18].

Intravenous Iron

Intravenous iron is appropriate in instances when oral iron is not tolerated by the patient, does not produce the desired effect, or when surgery is planned within six weeks of diagnosis [18]. Evidence regarding the reduction of transfusions following the use of intravenous iron is mixed [26,27]. For instance, Froessler et al. found that intravenous iron reduced the number of transfusions required by patients undergoing major abdominal surgery [28]. The PREVENTT (Preoperative Intravenous Iron to Treat Anemia in Major Surgery) trial, however, found that while intravenous iron increased the hemoglobin levels in patients, it did not reduce the number of transfusions required or the mortality rate of those patients [29]. Additional evidence regarding the effect of intravenous iron on transfusion requirements can also be found in systematic reviews [26].

Serious adverse reactions to modern intravenous iron preparations are not common [30,31]. Treatment with intravenous iron should be given as early as possible after iron deficiency has been identified. Shorter periods of treatment with intravenous iron have also been studied in relation to perioperative patients [18,32].

Timing of Administration

The benefits of intravenous iron depend on when the treatment is administered to the patient. Muñoz et al. [32] suggested that patients should begin iron treatment at least two to three weeks before their surgery. However, improvements in patients' hemoglobin levels may be noticed within seven to 10 days of treatment initiation. Therefore, it is crucial to identify iron deficiency during the preoperative assessment of a patient to give that patient enough time to treat their anemia before their surgery.

Erythropoiesis-stimulating agents

The ESAs are a group of drugs that includes synthetic erythropoietin. These drugs stimulate the production of red blood cells. They can be used in conjunction with iron therapy. Goodnough et al. [33] and Goodnough and Monk [34] found that patients who received ESAs with iron prior to undergoing orthopedic surgery required fewer transfusions of red blood cells. Furthermore, Weltert et al. [35] found that patients who underwent cardiovascular surgery and received ESAs had higher hemoglobin levels prior to their surgeries and required fewer transfusions.

Despite the benefits of ESAs, there is a risk of thromboembolic events associated with their use [36,37]. Additionally, the cost and availability of these drugs may limit their use. Current guidelines recommend that ESAs be used in patients with severe anemia and functional iron deficiency or an inadequate response to erythropoiesis, in cases where surgery cannot be delayed, and intravenous iron therapy alone would be insufficient to treat their anemia [38,39].

Red blood cell transfusion

Historical Practice

Perioperative anemia was generally managed through blood transfusions. However, the excessive use of transfusions presented several adverse effects for the patient, such as transfusion-related acute lung injury (TRALI), alterations in the immune system, infections, and increased risk of mortality [5,6].

Restrictive Transfusion Thresholds

Current evidence supports the use of restrictive thresholds for blood transfusions. In critically ill patients,

Hébert et al. [13] compared the use of a transfusion threshold of 10 g/dL to 7 g/dL. The higher threshold for transfusions did not provide any survival benefits for these patients. These findings were also observed in various patient subgroups within this study.

Carson et al. [14] studied patients over the age of 65 with cardiovascular diseases or those at risk of developing them after having surgery on their hips. They found that using a restrictive transfusion threshold of 8 g/dL did not result in worse outcomes for these patients when compared to using a more liberal transfusion threshold. These findings challenged the use of higher transfusion thresholds for these patients.

Similar findings have been reported in various meta-analyses, Cochrane reviews, and randomized studies [15,40]. The use of a restrictive transfusion strategy reduces the number of patients exposed to blood transfusions with no increase in adverse outcomes for the patients. These findings have remained consistent with various clinical and surgical settings.

Transfusion thresholds of approximately 7 to 8 g/dL have been supported for use in certain groups of patients [13-16,40]. These thresholds may not be used as target hemoglobin concentrations prior to elective major surgery. Patients who are stable and have hemoglobin levels between 7 g/dL and 8 g/dL may not require transfusions. However, patients who present with significant preoperative anemia should still have their anemia investigated and treated when possible [11,18]. The decision as to whether or not to treat the anemia should take into account the type of surgery, the urgency of the surgery, the amount of blood that may be lost during surgery, the presence of symptoms associated with anemia, the presence of cardiovascular disease, and the cause and severity of the anemia [11,16,18].

Current guidelines

In 2023, the American Association of Blood Banks (AABB) suggested that a hemoglobin value of 7 g/dL is suitable for stable patients. Patients with cardiovascular problems or those undergoing cardiac or orthopedic procedures usually aim for a value of around 8 g/dL [16]. However, hemoglobin values alone should not be the sole determinant of clinical decision-making for the patient. Other signs and the perfusion of the patient may provide additional information about the severity of the patient's condition.

Current approach to preoperative anemia

Preoperative anemia is currently approached by identifying anemia early, finding its cause, and treating any correctable deficiencies before the major elective surgery when possible [11,18]. Iron deficiency anemia is treated with oral or intravenous iron according to the time available for treatment, tolerance of the patient to the treatment, and the response to the treatment [18]. The ESAs are used in selected patients rather than routinely in all patients. Transfusion of red blood cells is used when indicated clinically, but not routinely, to treat the anemia due to an underlying correctable cause [16,18]. These treatments and strategies are part of the PBM program that aims to treat anemia, reduce blood loss, and use transfusions appropriately [41,42].

Patient blood management

Concept and Scope of PBM

Patient blood management is a multidisciplinary and evidence-based approach to perioperative care that aims at preventing and treating anemia before surgery, minimizing blood loss, and using blood transfusion appropriately [17,41,42]. It is supported by international policies such as the World Health Assembly (WHA) resolution on blood products and the recommendations from professional medical organizations. It has been implemented by individual hospitals and has grown into a strategy for managing blood within entire healthcare systems [17,43,44].

It includes three main components that can be incorporated into preoperative, anesthetic, and surgical care [42,44]. The first component is the optimization of erythropoiesis. This involves screening patients for anemia and iron deficiency at least three to four weeks before scheduled surgery [18,23]. For patients with limited time before their surgery, intravenous iron can be used to correct iron deficiency more rapidly [9,26,28,29,45]. Erythropoiesis-stimulating agents can also be used for patients at higher risk of anemia or with limited time before surgery, but only after iron deficiency has been corrected [38,39].

The second component of PBM focuses on minimizing blood loss during surgery. Techniques for minimizing blood loss include standardized measures to control bleeding and minimize blood loss during surgery. Point-of-care viscoelastic testing (such as thromboelastography and rotational thromboelastometry) can be used to minimize the need for plasma and platelet transfusions. Additionally, anesthetic techniques that help patients maintain normal body temperature and fluid balance can help minimize blood loss during surgery.

The third component includes the management of anemia and the conservation of blood products. A restrictive transfusion threshold of 7 g/dL to 8 g/dL (depending on the patient's condition and evidence of inadequate oxygen delivery to tissues) is recommended according to the 2023 guidelines from the AABB [16]. When transfusing a patient, one unit of blood should be transfused, and the medical staff needs to conduct a

complete assessment of the patient's condition before giving blood transfusions. The ERAS protocol will work with these measures through its established framework, which includes oxygen delivery optimization and postoperative movement activation.

Intraoperative Blood Conservation and Pharmacological Management

Management of perioperative anemia extends beyond the correction of hemoglobin concentrations prior to surgery alone. Intraoperative blood conservation is equally important in surgeries that are associated with substantial blood loss. Methods of conserving blood include surgical hemostasis, the use of topical hemostatic agents, maintenance of normothermia, and the correction of coagulation abnormalities. In patients at high risk of bleeding, coagulation tests performed at the point of care may be used to determine the best treatment for the patient, rather than providing blood products indiscriminately [46,47].

Tranexamic acid is a drug that reduces bleeding by preventing the breakdown of fibrin clots. The dosage and eligibility for tranexamic acid vary according to the specific surgery, the patient's renal function, and any contraindications to the drug. Additional doses of tranexamic acid are not routinely given without considering the length of the surgery, the amount of blood lost during the procedure, and any potential adverse effects of tranexamic acid [47,48].

Another technique that may be considered during surgeries with significant blood loss is the use of intraoperative cell salvage. Procedures associated with substantial blood loss include cardiac surgery, vascular surgery, and major orthopedic surgeries. Intraoperative cell salvage involves the collection and processing of blood during surgery, which is then reinfused into the patient. Additional methods of conserving blood include the maintenance of a patient's normothermia, avoiding hemodilution unnecessarily, and treating coagulopathy during surgery [47,48].

The decision to transfuse a patient should consider whether the patient is actively bleeding, their hemodynamic stability, the presence of ischemia in any organs, and their cardiovascular reserve. Restrictive transfusion thresholds of 7 g/dL to 8 g/dL may be appropriate in many clinical situations but should not be considered as acceptable preoperative hemoglobin concentrations for elective major surgeries. Instead, anemia should be treated prior to surgery if possible, to restore hemoglobin concentrations to within the normal range [16,23,47].

Effectiveness and Value

Patient blood management programs have been associated with a reduction in the use of blood products and improvements in the clinical and economic outcomes of patients [42-44]. In one health system that implemented a PBM program and tracked the outcomes of over 600,000 admissions, the use of blood products dropped by 41%, and there were also reductions in mortality, length of hospital stay, infections acquired in the hospital, and the costs of transfusions [43]. These findings suggest that coordinated PBM programs are beneficial for patients and the healthcare system, as opposed to implementing individual interventions for the treatment of preoperative anemia [42-44].

Challenges in implementation and health-system considerations

Late Identification of Anemia Under Tight Surgical Timelines

In many health centers, anemia is only identified days before surgery rather than weeks in advance, leaving little time for the patient to benefit from intravenous iron or ESA therapy [12,18,23]. Incorporating hemoglobin and iron studies earlier in the surgical referral or scheduling process will allow anemia to be identified and treated earlier.

Process and Resource-Access Barriers

There are several barriers to effective management of anemia. These include the lack of treatment protocols, lack of access to intravenous iron treatment services, the uncertainty regarding the reimbursement of intravenous iron, and the unclear responsibility within the healthcare community regarding who should treat anemic patients [12,18,23,43]. Each of these issues can be overcome by assigning responsibilities to the appropriate healthcare providers and treating patients with anemia within appropriate time frames before surgery.

Influence of Clinical Setting on Understanding

Another persistent barrier to the management of anemia is the understanding within the clinical setting that mild anemia does not have any significant clinical impact on a patient. Educating the clinical teams regarding the data on anemia in surgical patients, such as transfusion rates, infection rates, and length of stay in the hospital, can aid in the adoption of PBM practices [23,42-44]. Such educational opportunities can also include multidisciplinary meetings, electronic ordering alerts, and feedback to the clinical team

regarding the outcomes of these practices.

Role of Digital Tools in Implementation

Various digital tools in the electronic health records of health centers may aid in the implementation of PBM programs. Such aids include alerts for surgical patients with anemia, automated orders for anemia studies, and alerts for the clinical team to review these results before reaching transfusion thresholds [12,46]. These digital tools will improve adherence to these blood management practices and allow for early intervention for patients with anemia before their surgery.

Equity and Global Applicability

The burden of anemia is especially high among women, older adults, and those living in low- and middle-income countries (LMICs) [2]. Patient blood management strategies, such as the early detection of iron deficiency anemia and the appropriate use of intravenous iron, can be adapted to different healthcare systems around the world. However, the successful implementation of these strategies will depend on the availability of the resources needed for such treatments, as well as the development of approaches to anemia that take into account the needs of the local populations and their healthcare systems [2,18,43,44].

Alignment with guidelines and consensus

The 2023 AABB guidelines recommend restrictive hemoglobin thresholds for transfusion, with a threshold of about 7 g/dL for hemodynamically stable adults and a slightly higher threshold of about 8 g/dL for patients undergoing orthopedic or cardiac surgery or those with pre-existing cardiovascular disease. Other considerations for transfusion include the patient's clinical condition, specifically symptoms of inadequate oxygen delivery and ongoing blood loss [16].

Patient blood management recommendations from around the world include screening surgical patients for anemia and iron deficiency prior to surgery. If iron deficiency is identified, treatment should be initiated. In situations where there is limited time between the diagnosis of iron deficiency and the performance of surgery, intravenous iron should be considered. These PBM recommendations can be incorporated into perioperative care practices to improve the consistency of anemia and transfusion management [18].

The WHO and WHA have made recommendations regarding blood transfusion that emphasize the importance of access to safe, adequate, and high-quality blood products. Patient blood management recommendations, on the other hand, focus on reducing the number of transfusions that are performed unnecessarily to improve patient safety. Both of these recommendations work together to indicate that PBM should be integrated into perioperative care as a routine part of that care and not as an additional or optional intervention [17].

Evidence summary

Table *1* outlines key studies that have been included in this review of preoperative anemia management. The studies have been selected based upon their study design, the clinical relevance of their findings, and their influence upon perioperative anemia management today. The studies include observational studies of the outcomes of surgeries in anemic patients, randomized controlled trials (RCTs) of treatments for anemia, meta-analyses of the effectiveness of various treatments for anemia, and consensus recommendations from experts in the field of anemia management. The evidence table provides readers with an overview of the evidence that supports the current management of preoperative anemia. Furthermore, the table allows readers to compare the findings of each of the studies and to identify the evidence upon which the current recommendations for the management of preoperative anemia are based.

Author and reference no.	Year	Design	Population/setting	Key findings	Relevance
Hebert et al. (Transfusion Requirements in Critical Care (TRICC)) [13]	1999	Landmark RCT	Critically ill ICU patients	Restrictive threshold (7 g/dL) was safe; fewer transfusions	Foundation for modern transfusion guidelines
Carson et al. (Functional Outcomes in Cardiovascular Patients Undergoing Surgical Hip Fracture Repair (FOCUS)) [14]	2011	RCT	Elderly hip fracture patients	Restrictive transfusion (hemoglobin <7 g/dL) vs. liberal transfusion (hemoglobin <10 g/dL)	Supports restrictive transfusion strategies
Musallam et al. [1]	2011	Retrospective cohort	>227,000 non-cardiac surgery patients	Preoperative anemia independently increases mortality and complications	Demonstrates that anemia is a major independent risk factor and the importance of preoperative management of anemia
Litton et al. [26]	2013	Meta-analysis	Medical & surgical patients receiving IV iron (pooled from RCTs)	IV iron use reduces the need for blood transfusions with no increased risk of infection	Strong evidence of safety for IV iron therapy
Baron et al. [3]	2014	Prospective cohort	39,000 surgical patients	Mild anemia leading to increased complications, ICU admissions, and mortality	Strong evidence that anemia worsens outcomes
Froessler et al. [28]	2016	RCT	Abdominal surgery patients with anemia	IV iron reduced the need for blood transfusion and shortened recovery time	Supports preoperative IV iron use
Leahy et al. [43]	2017	Health-system implementation study	Four tertiary hospitals	PBM program reduced the need for blood transfusions by 20% to 40% and reduced complications	Demonstrates PBM effectiveness in real-world settings
Muñoz et al. [18]	2016	International consensus guidelines	Multidisciplinary global panel	Recommends hemoglobin screening, IV iron, and PBM pathways	Provides global standard guidance

TABLE 1: Evidence summary

TRICC: Transfusion Requirements in Critical Care, FOCUS: Functional Outcomes in Cardiovascular Patients Undergoing Surgical Hip Fracture Repair, RCT: Randomized controlled trial, PBM: Patient blood management

Future directions

Well-designed multicenter trials with clearly defined clinical endpoints are needed. Future studies should investigate the effect of preoperative intravenous iron, either as a standalone treatment or as part of a PBM program, on major clinical outcomes such as myocardial infarction, stroke, and mortality in different surgical populations [29,44]. The majority of the evidence regarding intravenous iron perioperatively focuses on its effect on transfusion requirements.

Further RCTs can provide additional information regarding the effects of restrictive transfusion strategies in different patient populations. The optimal timing of intravenous iron treatment also requires further investigation. Studies can investigate the shortest amount of time that intravenous iron can be administered preoperatively to provide comparable benefit to intravenous iron administered two to three weeks prior to surgery. Furthermore, the appropriate timing of iron and erythropoiesis-stimulating agents in patients whose surgeries cannot be delayed should also be investigated [32,38,39].

Patient blood management programs adapted for LMICs should also be evaluated. Clinical trials in these countries can investigate screening and treatment strategies adapted for these populations, which have a high prevalence of anemia [2,43,44]. Furthermore, digital interventions for the implementation of PBM programs can also be evaluated. For example, electronic health record alerts, order sets, and reviews of performance can increase adherence to PBM programs and allow for the monitoring of clinical outcomes

[12,46].

Patient-centered outcomes can also be investigated in future studies. Outcomes relating to the patient well-being of those treated for preoperative anemia can provide another perspective on the benefits of preoperative treatment of anemia. For example, outcomes relating to patient well-being can include the level of fatigue experienced by the patient post-surgery, the level of functional recovery of the patient, their quality of life, and their ability to become mobile independently of others post-surgery [44].

Finally, further economic evaluations of PBM programs are also needed. Studies investigating the cost-effectiveness of these programs can provide healthcare systems with information regarding the value of intravenous iron, perioperative infusion services, and the staffing requirements [43,44].

Conclusions

Perioperative anemia is a common condition among surgical patients but is treatable. Unfortunately, there are adverse surgical outcomes associated with this condition, such as infection, organ dysfunction, increased transfusion requirements, and increased postoperative mortality. The treatment of perioperative anemia includes early detection of the condition and the treatment of the anemia prior to the surgical procedure. Intravenous iron can be administered prior to surgery to quickly correct the anemia. Other treatments include the use of erythropoiesis-stimulating agents that increase red blood cell production in selected patients. Clinical trials such as the TRICC and FOCUS trials have supported restrictive transfusion strategies. These strategies are included in the current transfusion guidelines. Patient blood management programs focus on treating perioperative anemia by correcting anemia before surgery, reducing blood loss during surgery, and using blood transfusions appropriately. These programs reduce the exposure of patients to donor blood, improve outcomes, and reduce costs to the healthcare system.

However, there are several barriers to the treatment of perioperative anemia. Most patients are diagnosed with perioperative anemia too late for it to be treated effectively. Additionally, many hospitals do not use the protocols of PBM programs, and access to the treatments for perioperative anemia, such as intravenous iron or erythropoiesis-stimulating agents, is limited. Screening patients for anemia prior to surgery, utilizing PBM programs, and increasing the availability of these treatments will allow for the improvement of treatment for perioperative anemia. Perioperative anemia should not be considered a benign condition in surgical patients. The early recognition and treatment of this condition will improve the care of surgical patients and their recovery from surgery.

Additional Information

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All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

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