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PREOPERATIVE ANEMIA AS A MODIFIABLE RISK FACTOR FOR PERIOPERATIVE COMPLICATIONS AND THE ROLE OF PATIENT BLOOD MANAGEMENT

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ABSTRACT

BACKGROUND

Preoperative anemia is a common condition in patients undergoing surgical procedures and represents an important problem in perioperative medicine. Epidemiological data indicate that it affects approximately 25 to 40 percent of patients scheduled for surgery and is associated with an increased risk of adverse perioperative outcomes.

AIM

The aim of this study was to analyze the available scientific evidence regarding the prevalence, causes, and clinical impact of preoperative anemia in surgical patients and to evaluate its significance as a potentially modifiable risk factor within the framework of Patient Blood Management.

METHODS

A narrative review of the literature was performed using the PubMed and Google Scholar databases. Publications from 1999 to 2025 were considered. English and Polish language studies involving adult surgical patients were included, such as randomized controlled trials, meta analyses, systematic reviews, and cohort studies addressing the association between preoperative anemia and perioperative outcomes, as well as studies concerning Patient Blood

Management strategies.

RESULTS

The reviewed studies demonstrate that preoperative anemia is associated with an increased risk of perioperative mortality, postoperative complications, higher transfusion requirements, and prolonged hospitalization. The most frequent causes of preoperative anemia reported in the literature include iron deficiency, anemia of chronic disease, and deficiencies of vitamin B12 or folate. Evidence from the analyzed publications also indicates that strategies of Patient Blood Management, including early detection and treatment of anemia, minimization of blood loss, and rational use of transfusion therapy, may contribute to improved perioperative outcomes.

CONCLUSIONS

Preoperative anemia should be considered an important and potentially modifiable risk factor for adverse perioperative outcomes. Early diagnosis and causal treatment of anemia within the framework of Patient Blood Management represent important elements for improving the safety and effectiveness of surgical care.

Keywords: preoperative anemia, perioperative complications, blood transfusion, patient blood management, postoperative mortality

2. INTRODUCTION

2.1 DEFINITION OF PREOPERATIVE ANEMIA

Anemia is defined as a hemoglobin concentration below the reference values established by the World Health Organization: <13 g/dL in men and <12 g/dL in women [1]. In the perioperative setting, the use of a unified threshold of <13 g/dL regardless of sex is increasingly recommended for patients undergoing procedures associated with significant bleeding risk, as hemoglobin levels below this value are associated with a higher risk of transfusion and perioperative complications [2].

2.2 THE SCOPE OF THE PROBLEM OF PREOPERATIVE ANEMIA

Anemia represents a major global health challenge, affecting significant age groups and populations across different regions. According to analyses from the Global Burden of Disease Study 2021, the global prevalence of anemia in 2021 was 24.3%, corresponding to approximately 1.92 billion people affected worldwide. These analyses reveal clear differences in anemia burden depending on age, sex, and geographic region. Particularly high rates are observed among children under 5 years of age, women of reproductive age, and in regions of Sub-Saharan Africa and South Asia.

In individuals over 65 years of age, anemia is associated with an increased risk of hospitalization, poorer surgical outcomes, and higher overall mortality [3].

The global prevalence of anemia (24.3%) indicates a significant public health problem with direct clinical implications, including an increased risk of complications and worse surgical outcomes in patients with reduced hemoglobin levels.

2.3 WHY IS PREOPERATIVE ANEMIA A CLINICAL PROBLEM?

A study involving 7,738 patients undergoing cardiac surgery demonstrated that preoperative anemia was significantly associated with increased mortality and perioperative complications. Patients with anemia had more than a threefold higher risk of perioperative death compared with non-anemic patients (4.6% vs. 1.5%). Moreover, anemia was associated with a higher incidence of other serious complications, such as postoperative renal failure (18.5% vs. 6.5%) and prolonged hospital stay exceeding seven days (54% vs. 36.7%). These data highlight that anemia prior to cardiac surgery not only affects the risk of death but also influences the course and outcomes of surgical treatment, making it a significant risk factor in clinical practice [4].

In a study of 599 patients undergoing elective cardiac surgery, analysis showed that anemia was present in 76.1% of women and 26.7% of men. Patients with anemia had a greater burden of comorbidities. They were more frequently diagnosed with diabetes (53.8% vs. 38.9% in non-anemic patients), heart failure (51.4% vs. 28.3%), and prior cerebrovascular events (10.0% vs. 4.9%) [5].

The results also demonstrated a significantly higher risk of overall perioperative mortality in patients with anemia (6.4% vs. 2.6% in non-anemic patients), reflecting nearly a 2.5-fold increase in mortality [5].

RELEVANCE

Preoperative anemia is a common condition among patients preparing for surgical procedures and is identified in approximately 25 to 40 percent of patients scheduled for elective surgery. Reduced hemoglobin levels before surgery are associated with an increased risk of postoperative mortality, complications, a higher need for blood transfusion, and prolonged hospitalization. In recent years, particular attention has been given to the concept of Patient Blood Management aimed at early detection and correction of anemia, reduction of blood loss, and rational use of transfusion therapy. In this context, analysis of the role of preoperative anemia as a risk factor for adverse perioperative outcomes and evaluation of the significance of Patient Blood Management strategies represent an important scientific and clinical issue.

SCIENTIFIC NOVELTY OF THE STUDY

The scientific novelty of this study lies in the systematization of contemporary literature data on the prevalence, causes, and clinical consequences of preoperative anemia in surgical patients. The article analyzes evidence regarding the association of preoperative anemia with mortality, postoperative complications, the need for blood transfusion, and length of hospital stay, and also examines the role of Patient Blood Management strategies in the detection and correction of this condition.

AIM OF THE STUDY

The aim of this study is to analyze contemporary literature data on the prevalence, causes, and clinical consequences of preoperative anemia in patients undergoing surgical procedures and to evaluate its role as a potentially modifiable risk factor for adverse perioperative outcomes and the significance of Patient Blood Management strategies in its correction.

RESEARCH OBJECTIVES

1. To analyze the prevalence of preoperative anemia in patients undergoing surgical procedures according to published clinical studies.
2. To examine the main causes and pathophysiological mechanisms of preoperative anemia, including iron deficiency, anemia of chronic disease, and deficiencies of vitamin B12 and folate.
3. To analyze the association between preoperative anemia and perioperative outcomes, including mortality, postoperative complications, blood transfusion requirements, and length of hospital stay.
4. To examine the principles of Patient Blood Management and their role in the detection and treatment of preoperative anemia.

3. METHODOLOGY

STUDY DESIGN

A narrative review of the scientific literature was conducted focusing on preoperative anemia, its causes, prevalence, and its impact on perioperative outcomes in patients undergoing surgical procedures, as well as on the role of the Patient Blood Management strategy in the perioperative period.

PERIOD OF ANALYSIS

The literature analysis was performed from December 2025 to March 2026. Publications published between 1999 and 2025 were included in the review.

SOURCES OF INFORMATION

The search for publications was conducted in the electronic databases PubMed and Google Scholar. In addition, international guidelines and journal publications containing clinical guidelines were analyzed. The reference lists of the selected publications were also examined to identify additional relevant sources.

LITERATURE SEARCH STRATEGY

The search was performed using the following combinations of keywords:

- preoperative anemia and postoperative mortality
- preoperative anemia and perioperative complications

- iron deficiency and surgery
- anemia of chronic disease and surgery
- patient blood management and outcomes
- transfusion thresholds and surgery.

INCLUSION CRITERIA

Publications in English and Polish concerning adult patients aged 18 years and older undergoing cardiac and non-cardiac surgical procedures were included in the analysis. Randomized controlled trials, meta analyses, systematic reviews, and cohort studies evaluating the impact of preoperative anemia on perioperative outcomes and the effectiveness of Patient Blood Management strategies were considered.

EXCLUSION CRITERIA

Studies involving pediatric patients, publications not related to surgical patients, and studies not analyzing the impact of preoperative anemia on perioperative outcomes were excluded.

Selection and analysis of publications

The selected publications were analyzed with regard to their methodological design, the size of the study populations, the criteria used to define anemia, and their relevance to the aim of the study.

DATA ANALYSIS METHODS

Due to the narrative nature of the review, formal statistical analysis and meta analysis were not performed. The results were summarized based on qualitative analysis of the data presented in the selected publications.

4. RESULTS

4.1 PREVALENCE OF PREOPERATIVE ANEMIA

Preoperative anemia represents a significant epidemiological problem in the surgical patient population. In a large cohort study involving 227,425 adult patients undergoing non-cardiac surgery, 30.4% of patients (69,229/227,425) were found to have preoperative anemia according to WHO criteria [6].

In an analysis of patients undergoing non-cardiac surgery conducted across 28 European countries as part of a large observational project, preoperative anemia was found to be highly prevalent. Among 39,309 patients included in the study, the prevalence of anemia before surgery was 31.1% in men and 26.5% in women, confirming that approximately every third patient prepared for elective surgery presents with reduced hemoglobin levels [7].

A meta-analysis of 24 studies including a total of 949,445 patients demonstrated that preoperative anemia significantly increases the risk of postoperative mortality. The presence of anemia was associated with nearly a threefold increase in the risk of death [8]. The authors also emphasized that the risk increased with the severity of anemia, consistent with observations from other studies showing an association between lower hemoglobin levels and poorer prognosis.

In a multicenter study involving patients undergoing elective surgery, the prevalence of anemia defined as hemoglobin <13 g/dL regardless of sex was assessed. Of 1,074 patients, 411 (38.3%) had preoperative anemia. In this population, women were twice as likely as men to have reduced hemoglobin levels [9].

In a large retrospective study including 97,443 adult patients undergoing surgical procedures, preoperative anemia was present in 27.8% of patients according to WHO criteria. The severity of anemia varied within this population: 15.3% of cases were classified as mild, 12.0% as moderate, and 0.5% as severe. These findings indicate that nearly one-quarter of patients present for surgery with reduced hemoglobin levels. Furthermore, the prevalence of anemia varied by age and sex. In men, the proportion of anemia increased with age, from 6.0% in the 18–29-year age group to 47.8% among those aged ≥70 years. In women, anemia was more prevalent in two age groups: 18–49 years and ≥70 years [10].

A review study involving patients undergoing elective surgical procedures associated with high bleeding risk demonstrated that preoperative anemia affects between 23% and 45% of all patients, with iron deficiency and anemia associated with chronic or inflammatory disease being the most common etiologies [11].

Large retrospective studies in patients scheduled for surgery have shown that the prevalence of preoperative anemia ranges from approximately 5% to 78%, depending on the population studied and the criteria used for its definition.

In particular, among patients prepared for major surgical procedures, the prevalence ranged from 30% to 60%, meaning that as many as every third or even every second patient presented for surgery with reduced hemoglobin levels [12].

4.2 ETIOLOGY AND PATHOMECHANISMS OF PREOPERATIVE ANEMIA

4.2.1 Iron Deficiency

Iron deficiency anemia develops as a result of a negative iron balance, when iron loss (e.g., chronic gastrointestinal bleeding, heavy menstrual bleeding) or increased demand exceeds dietary intake and intestinal absorption capacity. Initially, iron stores in the liver and reticuloendothelial system become depleted (reflected by decreased ferritin levels), followed by reduced iron availability for erythropoiesis (decreased transferrin saturation). This leads to impaired hemoglobin synthesis in erythroblasts and the production of microcytic, hypochromic red blood cells [13].

The most common cause of preoperative anemia is iron deficiency, both absolute and functional. An international consensus on perioperative management indicates that iron deficiency accounts for the majority of anemia cases prior to major surgical procedures, particularly in populations at high risk of blood loss [2].

In a retrospective study of patients prepared for elective cardiac surgery, hematologic data were analyzed to determine the causes of anemia. Among patients with preoperative anemia, 23.1% were diagnosed with iron deficiency anemia, and an additional 6.6% were considered to have possible iron deficiency anemia [14].

4.2.2 Anemia of Chronic Disease

Anemia of chronic disease (ACD), also referred to as anemia of inflammation, develops in the setting of chronic immune system activation associated with inflammatory, malignant, or autoimmune diseases. Its pathogenesis results from complex disturbances in iron metabolism and impaired erythropoiesis induced by inflammatory mediators [15].

A key mechanism in anemia of chronic disease is increased production of hepcidin, a hormone synthesized in the liver in response to pro-inflammatory cytokines, particularly interleukin-6 (IL-6). Hepcidin binds to ferroportin (the only known transporter responsible for iron export from intestinal enterocytes and macrophages), leading to its degradation. As a result, iron release into the bloodstream is inhibited and intestinal iron absorption is reduced. This leads to hypoferremia, despite normal or even increased total body iron stores. Iron remains sequestered in reticuloendothelial cells and becomes unavailable to the bone marrow, resulting in so-called functional iron deficiency and impaired hemoglobin synthesis [15].

Additionally, pro-inflammatory cytokines directly inhibit the proliferation and differentiation of erythroid precursors in the bone marrow and reduce cellular responsiveness to erythropoietin (EPO). A shortened red blood cell lifespan is also observed. The combined effect of these mechanisms most commonly leads to the development of moderate, normocytic, normochromic anemia [15].

This type of anemia represents one of the key etiologies of anemia observed in patients preparing for surgical procedures. It is the second most common form of anemia worldwide, after iron deficiency anemia, accounting for up to 40% of all anemia cases and affecting more than 1 billion people globally [16].

A substantial proportion of cases consisted of anemia of chronic disease, diagnosed in 70.3% of patients with preoperative anemia. Within this group, nearly 30% had reduced iron stores, indicating a combination of limited iron availability and inflammatory mechanisms in the pathogenesis of anemia. Furthermore, 46.2% of patients with possible anemia of chronic disease exhibited features of functional iron deficiency, in which iron is present in the body but its release and utilization are impaired due to inflammatory mediators such as hepcidin [14].

4.2.3 Vitamin B12 or Folate Deficiency

Anemia due to vitamin B12 or folate deficiency is megaloblastic in nature and results from impaired DNA synthesis in rapidly proliferating cells, particularly erythroid precursors in the bone marrow. Vitamin B12 and folate are key cofactors in metabolic pathways necessary for the synthesis of thymidylate (dTMP), an essential component of DNA. Their deficiency leads to impaired DNA replication with relatively preserved RNA and protein synthesis, resulting in abnormal nuclear maturation. Some defective precursors undergo apoptosis within the bone marrow, further reducing the production of mature red blood cells [17].

In a retrospective study involving 410 adult patients qualified for major surgical procedures, preoperative anemia was identified in 41.5% of participants. Folate deficiency was diagnosed in 18.0% of patients, while vitamin B12 deficiency was found in 3.2% [18].

Data from large population-based analyses also indicate that preoperative anemia is often multifactorial in origin. In a study including over 39,309 patients undergoing elective surgery, anemia was present in 31.1% of men and 26.5% of women depending on the type of procedure, and a substantial proportion of cases showed features of both iron deficiency and inflammation [7]. The main causes of preoperative

anemia and their underlying mechanisms are presented in Table 1.

Table 1. The most common causes of preoperative anemia. Mixed etiology refers to cases, in which more than one pathogenic mechanism of anemia is present simultaneously, most commonly a combination of iron deficiency and inflammatory processes.

Cause	Estimated contribution to anemia	Dominant mechanism
Absolute iron deficiency [2]	30-50%	Blood loss or low iron intake
Inflammatory anemia [16]	20-30%	Inhibition of erythropoiesis by inflammatory cytokines (mainly IL-6)
Vitamin B12 or folic acid deficiency [2]	5-10%	Disturbed DNA synthesis
Mixed etiology [7]	about 30%	Overlapping mechanisms

4.3 IMPACT OF PREOPERATIVE ANEMIA ON PERIOPERATIVE OUTCOMES

4.3.1 Mortality and Complications

In an analysis of 13,843 adult patients undergoing cardiac surgery, the impact of severe preoperative anemia on treatment outcomes was assessed. Using propensity score matching, 401 patients with severe anemia were matched with 401 patients without anemia for comparative analysis. Operative mortality was significantly higher in the anemic group (12.7%) compared with patients without anemia (7.5%). The incidence of major postoperative complications was also higher among patients with anemia (27.4% vs. 17.5%). The rate of stroke was 1% in the anemic group compared with 0% in the control group [19].

In a retrospective analysis involving 85,989 adult patients undergoing non-cardiac surgery, the presence of moderate to severe preoperative anemia (Hb ≤9 g/dL) was associated with a significantly higher risk of 30-day postoperative mortality compared with patients with no anemia or mild anemia. In a propensity score–matched analysis, the 30-day mortality rate was 2.47% in patients with moderate or severe anemia versus 1.22% in those without anemia or with mild anemia [20].

In a retrospective cohort study including 310,311 elderly patients undergoing elective non-cardiac surgery, an association was observed between preoperative hematocrit levels and the risk of 30-day perioperative mortality. The data showed that the risk of death and postoperative cardiac events increased progressively as hematocrit values deviated from the normal range. Each one-percentage-point decrease below the reference range was associated with an average 1.6% relative increase in the risk of 30-day postoperative mortality [21].

4.3.2 BLOOD TRANSFUSIONS

In a large analysis of 15,222 patients undergoing elective total hip and knee arthroplasty, anemia was identified in 19.6% of patients. Those with preoperative anemia had a significantly higher risk of blood transfusion, reaching 44%, compared with 13.4% in patients without anemia—representing more than a threefold increase in transfusion rates [22].

In a large analysis of 200 patients undergoing emergency surgery, preoperative anemia was associated with more than a fourfold increase in the risk of blood transfusion and a doubling of the risk of postoperative complications. Moreover, anemic patients had a fourfold higher risk of prolonged hospital stay compared with patients with normal hemoglobin levels [23].

In a cohort of 797 patients undergoing elective cardiac surgery, the prevalence of preoperative anemia was 15% according to WHO criteria. Analysis of transfusion data demonstrated marked differences between patients with and without anemia: 53% of anemic patients required red blood cell transfusion on the day of surgery, compared with only 10% of non-anemic patients. Furthermore, this association was strongly related to anemia severity: 79% of patients with moderate or severe anemia required transfusion, compared with 40% of those with mild anemia [24].

4.3.3 Other Outcomes

In a retrospective study of 5,793 patients aged ≥60 years undergoing surgery for hip fracture, the relationship between hemoglobin concentration and functional recovery was analyzed. The primary endpoint was walking distance at hospital discharge. The results demonstrated a clear association between hemoglobin level and functional performance. The predicted walking distance at discharge increased progressively with higher hemoglobin levels: approximately 56 feet (17 m) at Hb 7 g/dL, 74 feet (23 m) at Hb 10 g/dL, and 92 feet (28 m) at Hb 12 g/dL. Higher mean postoperative hemoglobin concentrations were independently associated with greater walking distance at discharge, even after adjustment for confounding factors [25].

In a retrospective study including 234 adult patients undergoing elective hip or knee arthroplasty, the prevalence of preoperative anemia was 30.7%. Outcome analysis showed that patients with anemia had a significantly longer mean hospital stay compared with non-anemic patients (6.48 ± 1.2 days vs. 3.36 ± 0.3 days, respectively) [26]. The association between preoperative anemia and length of hospital stay reported in the literature is presented in Table 2.

Table 2. Length of hospital stay (days) according to the presence of preoperative anemia and sex [26]. Data are presented as mean ± standard deviation.

Group of patients	Average length of hospitalization (days)
Patients with preoperative anemia	6,48 ± 1,2
Patients without anemia	3,36 ± 0,3
Men with anemia	7,2 ± 2,4
Men without anemia	3,4 ± 0,5
Women with anemia	6,0 ± 1,2
Women without anemia	3,3± 0,3

A cohort study involving 200 adult patients undergoing emergency surgical procedures in Ethiopian teaching hospitals compared a group with preoperative anemia (n = 100) to a group without anemia. Anemia was defined according to WHO criteria. Patients with anemia had a 1.87-fold higher risk of developing postoperative complications compared with non-anemic individuals. Moreover, anemia was associated with significantly more frequent postoperative admissions to the intensive care unit: 20% among patients with anemia versus 3% among those without anemia [23].

In a retrospective study of 599 patients undergoing cardiac surgery at a medical center in Oman, preoperative anemia defined according to WHO criteria was present in 41.6% of patients. Anemic patients not only had a poorer clinical profile (with more frequent comorbidities) but also demonstrated a significantly higher risk of selected postoperative complications. This condition was associated with a higher incidence of renal failure (16.5% in patients with preoperative anemia vs. 9.1% in those without anemia) and multiorgan failure (6.4% vs. 2.3%, respectively). The median length of hospital stay also differed, averaging 9 days in patients with anemia compared with 8 days in those without preoperative anemia [5].

5. DISCUSSION

5.1 IS PREOPERATIVE ANEMIA MERELY A MARKER OF MORE SEVERE DISEASE?

Many authors have suggested that preoperative anemia may reflect a greater overall burden of comorbidities, such as cardiovascular disease, chronic kidney disease, or inflammatory conditions. However, numerous multivariable analyses and propensity score–matched studies have demonstrated that reduced hemoglobin concentration is an

independent predictor of adverse perioperative outcomes, even after adjustment for age, comorbidities, and other classical risk factors.

In a large analysis of patients undergoing total knee arthroplasty, anemic patients had higher rates of complications and mortality compared with non-anemic individuals, despite matching for comorbidities and the absence of blood transfusion. This finding indicates that anemia independently contributes to clinical risk [27].

Furthermore, in a study including more than 31,000 elderly patients undergoing vascular surgery, preoperative anemia was associated with a higher risk of 30-day mortality and cardiac complications in multivariable analysis, confirming its prognostic significance independent of the patient's overall health status [28].

5.2 ANEMIA AS A MODIFIABLE RISK FACTOR

Unlike many non-modifiable risk factors (such as age, sex, or certain comorbidities), preoperative anemia in most cases develops through mechanisms that are amenable to treatment, such as iron deficiency or other hematologic abnormalities. Importantly, the preoperative assessment period before elective surgery provides a therapeutic window that allows for targeted intervention prior to the procedure. This includes anemia screening, evaluation of iron status and other hematologic parameters, and appropriate causal treatment through supplementation or correction of hematopoietic deficiencies. In clinical practice, such measures can improve hemoglobin levels and potentially reduce the risk of transfusion and perioperative complications [29].

An additional argument for considering preoperative anemia a modifiable risk factor comes from studies evaluating the effectiveness of active treatment programs. In an analysis of patients scheduled for elective cardiac surgery, implementation of a preoperative anemia management program—primarily based on intravenous iron administration—led to a significant increase in preoperative hemoglobin levels and nearly a threefold reduction in blood transfusions compared with a cohort that did not receive such intervention. The intervention was also associated with a clear reduction in hospital length of stay and a lower incidence of perioperative complications [30].

5.3 PATHOPHYSIOLOGICAL RATIONALE FOR THE IMPACT OF ANEMIA ON PERIOPERATIVE COMPLICATIONS

The negative impact of anemia on the perioperative course is primarily related to a reduced oxygen-carrying capacity of the blood. Hemoglobin concentration is a key determinant of total arterial oxygen content, and its reduction leads to decreased oxygen delivery to tissues. This mechanism underlies the development of anemic hypoxia, in which, despite normal pulmonary gas exchange, oxygen supply to peripheral tissues is limited.

Under conditions of increased metabolic demand, characteristic of the perioperative period, the body's compensatory reserves may be insufficient, potentially contributing to organ dysfunction and adverse clinical outcomes [31].

Surgery itself increases tissue oxygen demand and activates inflammatory and metabolic processes, thereby enhancing susceptibility to hypoxia during the perioperative period [32]. Cellular oxygen deficiency leads to a shift toward anaerobic metabolism, lactate accumulation, impaired cellular function, and potentially organ damage [31].

The literature demonstrates that preoperative anemia is associated with a higher incidence of adverse clinical outcomes, including cardiovascular complications, organ dysfunction, prolonged hospital stay, and increased perioperative mortality. An elevated risk of infections and other postoperative complications has also been observed in patients with reduced preoperative hemoglobin levels. Although these associations are primarily observational, a plausible mechanism explaining poorer clinical outcomes may be reduced tissue oxygen delivery and an imbalance between oxygen supply and demand under surgical stress conditions [33].

5.4 KEY PILLARS OF PATIENT BLOOD MANAGEMENT

5.4.1 Patient Blood Management as a Systemic Model of Perioperative Care

Patient Blood Management (PBM) is a multidisciplinary, evidence-based strategy aimed at improving clinical outcomes through optimization of the patient's hematologic status, minimization of blood loss, and rational use of transfusion therapy. This concept extends beyond single interventions and represents a comprehensive model of care integrating preoperative, intraoperative, and postoperative measures.

Implementation of PBM has been associated with a reduction in allogeneic transfusions, fewer transfusion-related complications, and improved overall clinical outcomes in surgical patients. This approach emphasizes that blood management should focus not on transfusion itself, but rather on patient optimization and minimizing exposure to blood products [34].

5.4.2 Treatment of Preoperative Anemia as the First Pillar of PBM

According to current recommendations, early diagnosis and treatment of preoperative anemia constitute one of the key pillars of the Patient Blood Management strategy. Authors emphasize that preoperative anemia is associated with an increased risk of transfusion, postoperative complications, and prolonged hospitalization, which justifies the need for its active correction prior to surgery [35].

Within the PBM framework, systematic screening for the underlying cause of anemia is recommended, including evaluation for iron deficiency, followed by implementation of substitution therapy depending on the urgency of surgery and the severity of anemia. This approach allows for an increase in hemoglobin concentration before surgery and reduces exposure to allogeneic transfusions, representing a practical implementation of the concept that preoperative anemia is a modifiable risk factor [35].

5.4.3 Minimization of Blood Loss as the Second Pillar of PBM

In light of the presented data demonstrating increased risks of complications and transfusion in patients with preoperative anemia, the second pillar of Patient Blood Management reduction of intraoperative blood loss gains particular importance. Minimizing bleeding logically complements efforts to optimize hemoglobin levels before surgery, as even a well-prepared patient may lose a significant amount of blood during the procedure [36].

The literature indicates that strategies including refinement of surgical techniques, the use of antifibrinolytic agents, and intraoperative cell salvage effectively reduce the need for transfusions. For example, in a large analysis involving 872,416 patients undergoing hip and knee arthroplasty, the use of tranexamic acid was associated with a significant reduction in transfusion rates without an increase in thromboembolic complications or organ failure. These findings confirm that minimizing blood loss is not merely a technical aspect of care, but has a tangible impact on patient safety and perioperative outcomes [37].

5.4.4 Rational Use of Transfusion as the Third Pillar of PBM

The third pillar of Patient Blood Management focuses on the rational use of blood transfusions, shifting practice away from historically liberal transfusion thresholds toward an evidence-based strategy that reduces unnecessary transfusions and minimizes associated risks.

In the landmark Transfusion Requirements in Critical Care trial, a liberal transfusion strategy (hemoglobin threshold of approximately 10 g/dL) was compared with a more restrictive strategy in which transfusion was administered only when hemoglobin levels fell below 7 g/dL. The results of this randomized study demonstrated that the restrictive strategy was at least as effective—and in some patient groups even more beneficial—in terms of clinical outcomes. These findings challenged the previously widespread practice of maintaining higher transfusion thresholds [38].

Based on subsequent clinical evidence and analyses of randomized trials, the AABB (American Association of Blood Banks) guidelines recommend a transfusion threshold of approximately 7 g/dL of hemoglobin for hemodynamically stable adult patients in whom a restrictive strategy is appropriate, rather than the former 10 g/dL rule. For specific patient populations—such as those undergoing orthopedic or cardiac surgery, or patients with cardiovascular disease—the recommended threshold may be increased to approximately 8 g/dL [39].

Such restrictive thresholds not only reduce the total number of red blood cell units administered but also decrease exposure to potential transfusion-related complications (including immunologic reactions, circulatory overload, and infections), while maintaining clinical safety and without significantly worsening outcomes such as mortality or the incidence of cardiac complications [40].

5.4.5 Does the Implementation of PBM Truly Improve Clinical Outcomes?

In a study involving 884 patients aged ≥65 years undergoing surgery for hip fracture, implementation of a Patient Blood Management (PBM) program was associated with significant improvement in clinical outcomes. The proportion of patients receiving transfusion decreased from 43.5% before PBM implementation to 33.2% after full implementation. At the same time, the appropriateness of transfusion decisions increased from 54.0% to 94.7%, indicating more rational and guideline-adherent use of blood products [41].

The introduction of PBM was also associated with a reduction in median hospital length of stay from 12 to 9 days and a decrease in 30-day readmission rates from 12.0% to 6.8%. Importantly, blood transfusion remained independently associated with a higher risk of complications, further underscoring the importance of strategies aimed at limiting unjustified transfusions. These data suggest that PBM not only reduces transfusion rates but also meaningfully improves perioperative outcomes [41].

Available systematic data confirm that comprehensive implementation of Patient Blood Management translates into tangible clinical benefits. Literature analyses evaluating structured PBM programs have demonstrated that PBM

strategies are associated with reduced transfusion requirements, leading to a lower risk of complications related to allogeneic blood exposure and contributing to safer outcomes in both surgical and medical patients. A review addressing PBM implementation emphasized that adoption of these principles is linked not only to a reduction in transfusion rates, but also to fewer transfusion-related complications and lower mortality, while promoting more efficient and safer blood management practices [42].

Furthermore, the authors highlighted that the clinical benefits of PBM are accompanied by potential economic advantages, including reduced treatment costs and more efficient use of resources in both public and private healthcare systems. This underscores its value not only as a medical strategy, but also as a systemic healthcare approach [42].

An analysis of experiences from 12 countries indicates that implementation of PBM is associated with measurable clinical and organizational benefits. The authors emphasized that PBM leads to a reduction in unnecessary transfusions and transfusion-related complications, thereby improving patient safety. At the same time, improved resource utilization, greater system efficiency, and potential cost reductions were observed [43].

It was also noted that the positive effects of PBM stem from its comprehensive, interdisciplinary nature. The coordinated approach—encompassing patient optimization, minimization of blood loss, and rationalization of transfusion practice—is what enables PBM to meaningfully improve the quality of care and perioperative treatment outcomes [43].

5.5 CLINICAL IMPLICATIONS

The presented data indicate that preoperative anemia should be regarded as a significant and modifiable risk factor for perioperative complications, rather than merely a passive marker of a patient's general condition. In clinical practice, this necessitates systematic and early assessment of hemoglobin levels in patients scheduled for surgical procedures associated with significant bleeding risk. Evaluation of iron status parameters, vitamin B12, and folate levels should be considered sufficiently early to allow for implementation of causal treatment before the planned operation.

The available evidence also implies the need for a shift in transfusion decision-making. Blood transfusion should not be treated as a routine response to reduced hemoglobin levels, but rather as an intervention with clearly defined clinical indications. The use of restrictive transfusion thresholds and individualized assessment of anemia tolerance allow for reduced exposure to blood products without compromising patient safety.

Equally important is the implementation of Patient Blood Management principles as an organizational standard in perioperative care. Integration of the three pillars of PBM requires interdisciplinary collaboration among surgeons, anesthesiologists, and internists. Structured, evidence-based clinical pathways may contribute to improved quality of care, shorter hospital stays, and reduced perioperative complications.

From a broader perspective, PBM implementation also has systemic implications. Reducing unjustified transfusions and transfusion-related complications may lead to more efficient resource utilization and lower healthcare costs. Therefore, early identification and treatment of preoperative anemia represent not only a strategy to enhance individual patient safety, but also an approach to optimizing the performance of the healthcare system as a whole.

Although the literature reviewed in this study describes the individual components of Patient Blood Management, the overall clinical rationale of this strategy should be emphasized. The available evidence indicates that PBM integrates three complementary elements: early identification and treatment of preoperative anemia, minimization of perioperative blood loss, and rational use of transfusion therapy. The combination of these measures contributes to reducing exposure to allogeneic blood transfusion and may improve perioperative outcomes in surgical patients.

5.6 FUTURE RESEARCH DIRECTIONS

Future research should focus on prospective and randomized clinical studies evaluating the effectiveness of preoperative anemia correction on perioperative outcomes. Particular attention should be given to determining optimal diagnostic algorithms for identifying the underlying causes of anemia in surgical patients and to assessing the effectiveness of different treatment strategies, including iron therapy and other targeted interventions. Further studies are also needed to evaluate the long term clinical and economic impact of comprehensive Patient Blood Management programs in various surgical populations.

5.7 LIMITATIONS OF THE EVIDENCE

Most of the available evidence regarding the impact of preoperative anemia on perioperative outcomes derives from observational studies and retrospective cohort analyses, which limits the ability to establish definitive causal relationships. Anemia frequently coexists with chronic diseases that may independently influence postoperative

prognosis.

Additionally, studies have used varying definitions of anemia and have included heterogeneous surgical populations, which may contribute to variability in reported outcomes. In the case of Patient Blood Management, part of the available data originates from implementation analyses and institutional experiences with adopting these strategies, which may also limit the generalizability of findings.

Despite these limitations, the consistency of observed associations across different populations and the reproducibility of findings strengthen the conclusion that preoperative anemia is a significant and potentially modifiable risk factor.

Taken together, the available evidence indicates that preoperative anemia is highly prevalent among surgical patients and is consistently associated with an increased risk of perioperative complications, mortality, blood transfusion, and prolonged hospitalization. The reviewed studies demonstrate that reduced hemoglobin levels are not only a marker of comorbidity but also an independent predictor of adverse outcomes. These findings support the importance of early identification and causal treatment of anemia before surgery. Within this context, implementation of Patient Blood Management strategies represents a practical approach to improving perioperative safety and optimizing clinical outcomes.

6. CONCLUSIONS

The literature analysis conducted in this study indicates that preoperative anemia is widely prevalent among patients undergoing surgical procedures and is identified in approximately one quarter to one third of patients preparing for surgery. The results of the analyzed studies demonstrate that reduced hemoglobin levels before surgery are associated with an increased risk of perioperative mortality, postoperative complications, a higher need for blood transfusion, and prolonged hospitalization.

The analysis of the literature also shows that the most common causes of preoperative anemia include iron deficiency, anemia of chronic disease, and deficiencies of vitamin B12 and folic acid, while in many cases anemia has a multifactorial origin.

The available evidence confirms that preoperative anemia may be regarded as a potentially modifiable risk factor for adverse perioperative outcomes. Therefore, early diagnosis of anemia and causal treatment within the framework of Patient Blood Management, including optimization of hemoglobin levels, reduction of blood loss, and rational use of transfusion therapy, represent important elements for improving the safety and effectiveness of surgical treatment.

DISCLOSURE

AUTHORS' CONTRIBUTIONS

All authors have read and agreed with the published version of the manuscript.

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The authors declare no conflict of interest.

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