

Optimising Surgical Outcomes: Evidence-based Interventions across the Three Pillars of Patient Blood Management

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Abstract

Patient blood management (PBM) is an evidence-based, patient-centred approach that improves perioperative outcomes by optimising red cell mass, minimising bleeding and coagulopathy, and enhancing tolerance to anaemia. Contemporary evidence shows that PBM reduces transfusion, complications, length of stay, and costs across surgical and high-risk populations. This review summarises the key evidence supporting PBM interventions most relevant to anaesthetic practice.

Key words: patient blood management, perioperative anaemia, surgical bleeding, resource-limited settings

INTRODUCTION

Over the last 20 years, the patient blood management (PBM) movement has revolutionised perioperative care. Allogeneic blood transfusion, which had previously been the most common intervention for anaemia and haemorrhage, is now recognised as a nonbenign intervention associated with immunomodulation, infectious and noninfectious complications, thromboembolic events, increased postoperative morbidity, and, in certain oncologic populations, cancer recurrence.^{1,2} Economic analyses have also shown that transfusion and the associated complications have significant direct and indirect costs.³ This evidence, in concert, has resulted in a paradigm shift toward prevention, evidence-based, and blood-saving perioperative strategies.

Robust literature demonstrates that the practice of following three synergistic pillars of PBM is associated with reduced transfusion rates; fewer postoperative complications; shorter hospitalisation; and lower overall cost in surgical, trauma, obstetric, and critical care services across settings: (1) red cell mass optimisation, (2) minimisation of blood loss and coagulopathy, and (3) optimisation of physiological tolerance to anaemia.⁴ This article provides a contemporary summary of relevant evidence for the last decade combining perioperative trials, large cohort studies, and implementation reports to identify best practices for PBM interventions in surgical outcomes.

PILLAR 1: OPTIMISING RED CELL MASS

The Burden and Impact of Preoperative Anaemia

Preoperative anaemia is among the most prevalent and clinically significant comorbidities in surgical populations. Large multicentre studies and meta-analyses show that 30%–40% of patients presenting for major surgery are anaemic. These findings reflect the global burden of anaemia, affecting an estimated 24.3% of the world's population (>1.9 billion people), with the greatest impact in low- and middle-income countries. Contemporary perioperative guidelines therefore recognise anaemia as a serious, treatable condition and recommend routine screening before major surgery.⁵

The clinical consequences of preoperative anaemia extend across the perioperative continuum. Large observational cohorts consistently show higher rates of infection, acute kidney injury, myocardial infarction, multisystem organ failure, and increased short- and long-term mortality. Even mild anaemia confers incremental risk.⁶ From a system perspective, anaemic patients are more likely to receive transfusions, require reoperation, experience prolonged intensive care unit (ICU) and hospital stay, and be discharged to higher levels of care. These associations are consistent across surgical specialties, underscoring anaemia as a common and modifiable determinant of perioperative risk.

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Despite this, anaemia remains frequently undiagnosed and untreated, particularly in health systems with fragmented preassessment pathways or limited access to diagnostics and iron therapy. Studies from Europe, Latin America, and Africa reveal a gap between awareness of PBM principles and the availability of structured anaemia management pathways. As a result, readily treatable causes of anaemia such as iron deficiency often go undetected, leaving transfusion as a default rescue strategy and amplifying complications, length of stay, and costs, effects that are especially unsustainable in resource-limited settings.⁷

Integrating Anaemia Diagnosis and Correction into Surgical Pathways

Pillar 1 strategies are now guided by a clear evidence-based framework that treats preoperative anaemia as a modifiable clinical condition. Consensus recommendations converge on a practical message: All patients undergoing major elective surgery should be screened for anaemia, ideally ≥ 4 weeks preoperatively. Standard evaluation includes haemoglobin (Hb), ferritin, transferrin saturation, C-reactive protein, and renal function, with vitamin B₁₂ and folate to be assessed when indicated. Absolute iron deficiency and inflammation-related iron restriction are the predominant causes of perioperative anaemia. Structured diagnostic algorithms help distinguish between these mechanisms, enabling targeted treatment rather than transfusion-based rescue.⁸

From an implementation perspective, Pillar 1 offers a high-value, scalable entry point into PBM. World Health Organization guidance prioritises anaemia detection and treatment as an early intervention, emphasising that simple diagnostics and cost-effective therapies can be applied even in constrained environments.⁹ Evidence from Latin America and other middle-income regions shows that standardised screening and iron pathways without advanced technology reduce transfusion demand and relieve pressure on fragile blood supplies. Practical measures include embedding anaemia assessment into surgical booking, using “traffic light” Hb thresholds, and aligning preassessment and surgical services around shared protocols.¹⁰

Therapeutic Evidence

Iron replacement remains the cornerstone of Pillar 1 for patients with iron deficiency. Although intravenous iron is preferred when time is limited or absorption is unreliable, perioperative guidelines recognise oral iron as appropriate for low-risk patients and resource-limited settings. In elective surgery with adequate lead time (≥ 6 – 8 weeks), oral iron is often first-line, with intravenous (IV) iron reserved for nonresponders or urgent cases. A recent systematic review in noncardiac surgery demonstrates that preoperative oral iron alone can achieve clinically meaningful Hb increases, enabling many patients to avoid transfusion.^{10,11}

In high-volume, resource-limited settings such as orthopaedic and general surgery in low- and middle-income countries, early oral iron therapy offers a pragmatic, low-cost entry point to PBM. Despite slower and less predictable Hb responses than IV iron, its use can reduce dependence on scarce blood supplies, transfusion rates, and perioperative morbidity. Systematic reviews emphasise that iron route selection should be individualised according to local resources, surgical timing, patient tolerance, and anticipated delays (Table 1).¹²⁻¹⁸

Although anaemia treatment should ideally begin as early as possible, it is never too late to intervene. Clinical trials demonstrate that treatment initiated even 1 day before surgery can result in sustained Hb improvement and reduced transfusion requirements. In patients with anaemia undergoing major abdominal surgery, a single preoperative dose of IV iron administered approximately 2 weeks before surgery produced significantly greater Hb recovery than placebo, persisting for at least 6 months postoperatively.¹⁹

PILLAR 2: MINIMISING PERIOPERATIVE BLOOD LOSS AND COAGULOPATHY

Surgical and Anaesthetic Approaches

Meticulous surgical technique remains the primary strategy to minimise bleeding. Across specialties, minimally invasive approaches consistently reduce blood loss and transfusion exposure. Comparative studies in colorectal, gynaecological, thoracic, and orthopaedic surgery demonstrate that laparoscopic and robotic techniques are associated with less bleeding, lower transfusion rates, and shorter hospital stays than open surgery, with transfusion reductions of up to 40% in abdominal cancer surgery. Adjunctive measures including advanced energy devices, topical haemostatics, and haemostasis checklists further reduce blood loss. In cardiac and major vascular surgery, structured haemostasis bundles significantly decrease reexploration, complications, and transfusion requirements.²⁰

Anaesthetic management is central to preserving physiological conditions for effective haemostasis. Endotheliopathy related to inadequately treated shock, hypothermia, acidosis, hypocalcaemia, and dilutional coagulopathy are key drivers of bleeding. Even mild hypothermia impairs platelet function, and trials consistently show that active warming reduces blood loss and transfusion. Maintenance of normal ionised calcium is embedded in major haemorrhage algorithms, supported by evidence that early supplementation improves coagulation and reduces vasopressor use.²¹

Goal-directed fluid therapy (GDFT) further limits haemodilution while maintaining perfusion. Randomised trials and meta-analyses show that GDFT reduces transfusion, complications, and length of stay compared with liberal crystalloid strategies, particularly in high-risk surgery.²² Emerging evidence supports haemodynamic-guided anaesthesia strategies, including targeted arterial pressure control with stroke-volume optimisation, restrictive and goal-directed fluid therapy, and ventilation approaches aimed at limiting venous congestion (e.g., lower positive end-expiratory pressure in selected contexts), which are associated with reduced intraoperative bleeding and improved surgical field conditions in specific procedures.²³ Figure 1 compares different evidence-based PBM interventions across the surgical pathway, categorised by strength of evidence supporting their clinical impact and effects on healthcare costs.

Pharmacologic Interventions

Pharmacologic strategies are a core component of PBM Pillar 2, complementing surgical and anaesthetic measures by directly modulating coagulation and fibrinolysis. Among these, tranexamic acid (TXA) has the strongest evidence base. Meta-analyses across surgical specialties show that a single preoperative IV dose reduces blood loss and lowers transfusion

Table 1 – Preoperative Iron Therapy: Oral versus Intravenous

Author/Year	Population & Design	Intervention	Key Haemoglobin Findings	Impact on Transfusion/Clinical Outcomes	Relevance to PBM Pillar 1
Keeler et al., 2017. ¹²	RCT Colorectal cancer n = 116	Preoperative IV ferric carboxymaltose vs. oral ferrous sulphate	IV iron achieved greater preoperative Hb and iron repletion than oral iron	Transfusion rates were similar; IV iron reduced postoperative anaemia	Oral iron remained effective when IV iron was unavailable, producing a modest Hb increase
Meyer et al., 2022. ¹³	Meta-analysis of RCTs (4 abdominal surgery trials)	IV vs. oral iron	IV iron corrected preoperative iron-deficiency anaemia more effectively	No difference in transfusion rates between oral and IV iron	Oral iron remained beneficial when IV iron was not feasible
Talboom et al., 2023. ¹⁴	Multicentre RCT in 202 colorectal cancer patients	IV ferric carboxymaltose vs. oral ferrous fumarate	Preoperative Hb normalisation was uncommon with both treatments, but IV iron achieved higher Hb at all subsequent time points	Restoration of iron stores was feasible only with IV iron	In selected patients, delaying surgery may enhance Hb normalisation; IV iron provides faster Hb improvement
Ng et al., 2019. ¹⁵	Systematic review (6 RCTs, n = 372)	IV vs. oral iron	IV iron increased Hb and ferritin, but evidence was limited	No difference in blood transfusion	Oral iron still effective when IV unavailable
Abdullah et al., 2021. ¹⁶	Propensity-matched case-control study (89 patients)	IV vs. oral iron	Not included	Transfusion rates were similar; IV iron reduced length of stay	Oral iron beneficial when IV iron is not feasible
Yue et al., 2025. ¹⁷	Meta-analysis of 12 RCTs (n = 930; search to December 2023)	Preoperative IV iron vs. oral iron	IV iron improved Hb (MD +0.77 g/dL; 95% CI 0.30–1.23)	Transfusion rates and volumes were similar; length of stay and mortality did not differ between groups	Findings support individualised selection of iron therapy based on time to surgery, efficacy, and adverse effects
Park et al., 2024. ¹⁸	RCT: Rectal cancer preoperative Chemoradiotherapy	Oral ferrous sulphate vs. IV ferric carboxymaltose	Rectal cancer preop CRT	In progress	Ongoing (protocol published)

Abbreviations: Hb, haemoglobin; IV, intravenous; RCT, randomised controlled trial

Evidence summary comparing oral and intravenous iron for preoperative anaemia in surgical patients. The table highlights haemoglobin response, transfusion outcomes, and relevance for implementation within patient blood management Pillar 1

rates by up to 70% without increasing thromboembolic risk. Recent pooled analyses in major orthopaedic surgery, including more than 9000 patients, confirm consistent reductions in blood loss and transfusion exposure, with no safety signal when TXA is used at recommended doses.²⁴ Its low cost and ease of administration make TXA particularly valuable in resource-limited settings.²⁵

Coagulation factor concentrates, particularly four-factor prothrombin complex concentrate (4F-PCC) and fibrinogen concentrate (FC), enable targeted correction of coagulopathy, especially in settings where timely access to plasma-based products is limited. In major surgery, 4F-PCC is superior to plasma for bleeding related to coagulation factor deficiency and is preferred for urgent reversal of vitamin K antagonist-associated bleeding, achieving effective haemostasis in over 85% of patients with fewer transfusion-related complications.²⁶ For many direct oral anticoagulant-associated major bleeding events, particularly those related to factor Xa inhibitors, available data suggest that 4F-PCC can partially attenuate anticoagulant effects and may improve haemostasis.

Regarding FC, a 2024 systematic review and meta-analysis of randomised cardiac surgery trials concluded that FC and cryoprecipitate provide

comparable control of bleeding, transfusion requirements, thrombotic complications, and mortality.²⁷ A recent randomised study confirmed similar efficacy in restoring fibrinogen levels after cardiopulmonary bypass while highlighting practical advantages of FC, including standardised dosing, rapid reconstitution, and lower volume load.²⁸ An accompanying economic analysis from the FIBRES programme suggests that when in-hospital resource use is considered, FC is cost-neutral or potentially cost-saving, a finding of particular relevance for resource-constrained health systems.²⁹

Desmopressin has a more selective role. Meta-analyses in cardiac surgery show modest reductions in blood loss and red cell use without clear effects on transfusion rates or reoperation.³⁰ It is best reserved for selected indications such as uraemic platelet dysfunction, antiplatelet exposure, or mild von Willebrand disease.

Haemostatic Diagnostics

Conventional coagulation tests (CCTs), including prothrombin time (PT), international normalised ratio (INR), activated partial thromboplastin time (APPT), fibrinogen concentration, and platelet

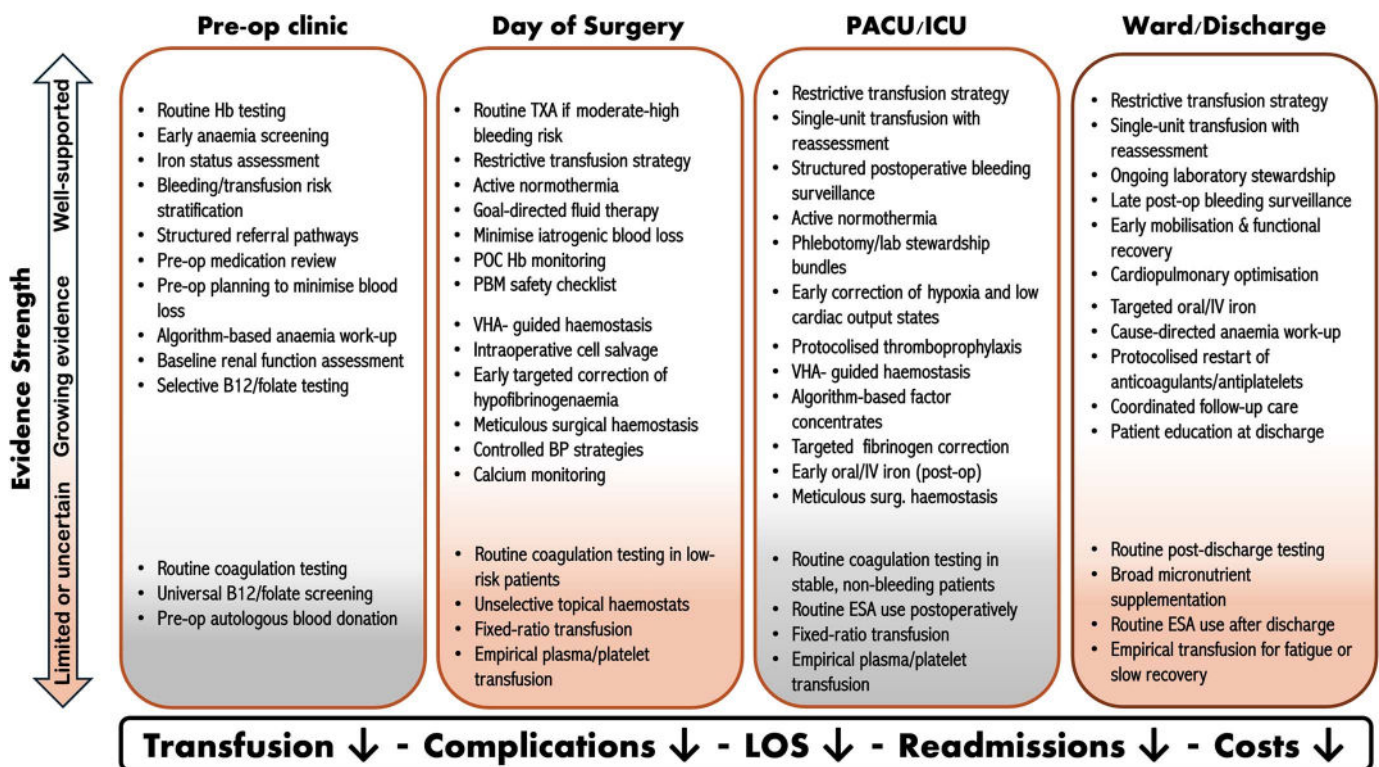


Figure 1 – Evidence-based impact of patient blood management interventions across the surgical pathway in moderate–major surgery, stratified by quality of evidence. Hb, haemoglobin; TXA, tranexamic acid; VHA, viscoelastic haemostatic assays; ESA, erythropoiesis stimulant agents; IV, intravenous

count, have traditionally been used to assess perioperative haemostasis, but provide a limited and delayed view of coagulation. As platelet-poor plasma assays, they fail to reflect whole-blood interactions and poorly predict surgical bleeding, particularly under perioperative conditions such as hypothermia, haemodilution, and acidosis. PBM-focused reviews consistently demonstrate the low diagnostic yield of routine, nonselective testing, supporting a shift toward selective, indication-based use.³¹ Consequently, contemporary PBM frameworks position CCTs as complementary rather than primary tools for guiding haemostatic therapy.

Viscoelastic haemostatic assays (VHAs), including thromboelastography and rotational thromboelastometry, overcome key limitations of CCTs by providing real-time, whole-blood assessment of clot initiation, propagation, strength, and lysis. By capturing the integrated contributions of fibrinogen, platelets, red cells, and fibrinolysis, VHAs enable early, mechanism-specific detection of coagulopathy and support goal-directed therapy, reducing reliance on empirical or ratio-based transfusion.³² Their integration into PBM algorithms enhances precision haemostatic management and reduces diagnostic uncertainty during active bleeding.

Randomised trials and meta-analyses demonstrate that VHA-guided haemostatic algorithms outperform conventional coagulation test-based management, reducing blood product exposure, bleeding, and reinterventions across cardiac surgery, liver transplant, and complex thoracic procedures without increased thromboembolic risk.³³ Large pooled analyses suggest additional mortality benefit when VHA guidance is embedded within structured PBM pathways,

and current guidelines recognise viscoelastic-guided management as a cornerstone of modern PBM practice.³⁴⁻³⁶

Cell Salvage and Autologous Blood Technologies

Intraoperative cell salvage (ICS) is a core component of PBM Pillar 2, aimed at reducing exposure to allogeneic red blood cell (RBC) transfusion during major surgery. The most recent Cochrane systematic review, including 106 randomised trials and 14 528 patients, shows that ICS significantly reduces the proportion of patients receiving allogeneic transfusion, with an approximate 38% relative risk reduction and an absolute reduction of around 20%. ICS also results in a modest but clinically meaningful reduction in transfused RBC volume, saving approximately 0.6–0.7 units per patient, particularly in spinal and cardiac surgery.³⁷ Importantly, ICS is not associated with increased mortality, thromboembolic events, or infection, supporting its safety and effectiveness.

Beyond transfusion reduction, ICS has been evaluated in high-risk obstetric and trauma settings. In the multicentre SALVO trial, routine ICS during caesarean section was safe and produced a modest reduction in donor blood transfusion, most evident in emergency procedures, without differences in maternal morbidity or length of stay.³⁸ A complementary meta-analysis of 24 studies showed higher postoperative Hb, fewer transfusion-related adverse events, and shorter hospital stay.³⁹ Observational trauma data further suggest that, when embedded within structured protocols and where setup costs are offset, ICS can deliver clinically meaningful volumes of autologous red cells without compromising safety.⁴⁰

Evidence for Pillar 2 Interventions

The effectiveness of Pillar 2 is supported by evidence for individual measures and, more convincingly, for bundled PBM programmes. In cardiothoracic surgery, a multispecialty Pillar 2 bundle incorporating haemostasis checklists, viscoelastic testing with decision support, and protocolised postoperative escalation achieved an approximately 60% reduction in blood product use within 12 h after cardiopulmonary bypass, with sustained benefits at 1 year and substantial cost reductions.²⁰ Similarly, a large multicentre observational study of 3839 cardiac surgical patients showed that implementation of a structured PBM algorithm was associated with lower chest drain losses, reduced transfusion rates, less postoperative acute kidney injury, and shorter hospital stay, demonstrating clinical and economic benefits beyond transfusion metrics alone.⁴¹

In major trauma and orthopaedic surgery, bundled Pillar 2 strategies deliver clinically meaningful improvements when embedded within algorithm-based care. In a pragmatic randomised trauma trial, a VHA-guided, goal-directed approach within a massive transfusion protocol improved 28-day survival and reduced early plasma and platelet exposure compared with CCTs.⁴² Real-world data from a Level 1 trauma centre confirm lower short-term and midterm mortality and reduced blood product wastage without increased overall costs.⁴³ In orthopaedic surgery, multifaceted PBM programmes are associated with reduced red cell use, lower composite morbidity and mortality, fewer 30-day readmissions, and consistent transfusion reductions with adjunctive TXA, without increased thromboembolic risk.⁴⁴

PILLAR 3: OPTIMISING PHYSIOLOGIC TOLERANCE TO ANAEMIA

Restrictive Transfusion Strategies

Restrictive transfusion practice, implemented as a bundle including Hb thresholds of 7–8 g/dL, single-unit transfusion with reassessment,

and physiology-based triggers, has strong evidence of effectiveness in surgical populations. A meta-analysis of 14 randomised trials showed that restrictive strategies halved intraoperative RBC transfusion (relative risk [RR] 0.53) and reduced overall perioperative transfusion exposure (RR 0.70), without differences in 30-day mortality.⁴⁵ Table 2 shows evidence-based RBC transfusion thresholds across different clinical contexts.^{46,59,60}

At a system level, a large meta-analysis of multimodal PBM programmes encompassing 235 779 surgical patients demonstrated a 39% reduction in transfusion, fewer RBC units per patient, lower complication rates (RR 0.80), a modest mortality reduction (RR 0.89), and shorter hospital stay (standardised mean difference [SMD] -0.45 days).⁴⁶ These findings are supported by real-world data from gastrointestinal surgery, where PBM implementation reduced transfusion and overtransfusion rates by 25% and 20%, respectively, without increases in morbidity, mortality, or length of stay.⁴⁷

Physiological Optimisation

Perioperative physiological optimisation to tolerate anaemia is best supported by goal-directed strategies that maintain adequate oxygen delivery (DO₂) by optimising preload, cardiac output, and perfusion pressure, rather than reliance on Hb thresholds alone. A large systematic review and meta-analysis of 76 noncardiac surgical trials showed that goal-directed haemodynamic therapy (GDHT) reduced hospital length of stay (SMD -0.72 days) and demonstrated a signal toward lower mortality, with greatest benefit in high-risk patients.²³

An updated meta-analysis including 65 trials further showed that DO₂-targeted optimisation reduced postoperative acute kidney injury (odds ratio [OR] 0.64), particularly in major abdominal and orthopaedic surgery when fluids and inotropes were combined.⁴⁸ In

Table 2 – Evidence-based Red Blood Cell Transfusion Thresholds across Different Clinical Contexts^{46,59,60}

Clinical Context	Recommended Transfusion Threshold	Key Considerations
Stable, non-bleeding adult (medical/surgical)	Hb <7 g/dL	Assess symptoms, haemodynamics, oxygenation; use single-unit transfusion with reassessment
Major surgery (stable postop)	Hb <7–8 g/dL	Individualise based on symptoms, comorbidities, physiological tolerance
Orthopaedic surgery (hip fracture/arthroplasty)	Hb <7–8 g/dL	Consider functional status, mobility goals, cardiovascular disease
Cardiac surgery (stable postop)	Hb <7.5–8 g/dL	Restrictive strategies are noninferior to liberal approaches
Critical illness (ICU, non-bleeding)	Hb <7 g/dL	Avoid transfusion based on Hb alone; optimise oxygen delivery
Sepsis/septic shock (after resuscitation)	Hb <7 g/dL	No benefit of liberal thresholds once haemodynamically stabilised
Acute coronary syndrome (stable)	Hb <8 g/dL*	Individualise decisions; avoid liberal transfusion without symptoms or instability
Chronic cardiovascular disease (stable)	Hb <8 g/dL	Consider symptoms, myocardial ischaemia, functional capacity
Active bleeding/major haemorrhage	Hb ~7–9 g/dL	Transfuse based on clinical status, bleeding rate, haemostasis protocols
Traumatic brain injury (non-bleeding)	Hb ~7–8 g/dL*	Individualise according to neurological status and cerebral ischemia risk; avoid unnecessary transfusion
Obstetric patient (postpartum, stable)	Hb <7 g/dL	Consider symptoms, ongoing bleeding, and haemodynamic status
Chronic anaemia (stable, ambulatory)	Avoid routine transfusion	Treat underlying cause; transfuse only if symptomatic or unstable

Abbreviations: Hb, haemoglobin; ICU, intensive care unit

* Evidence evolving; individualisation required

elderly hip-fracture patients (n = 551), GDHT within an enhanced recovery pathway reduced haemodynamic instability, postoperative complications, transfusion exposure (from 73.5% to 44.4%), length of stay (from 11 to 8 days), and improved 1-year survival (from 73.4% to 83.8%), illustrating how a physiology-first approach enhances anaemia tolerance and clinical outcomes in vulnerable populations.⁴⁹

A complementary line of evidence for Pillar 3 physiological optimisation focuses on tissue oxygenation and perfusion-guided management to prevent regional hypoxia during restrictive transfusion practice. In adult cardiac surgery, a meta-analysis of 12 randomised trials (n = 1868) showed that cerebral oximetry-guided interventions reduced postoperative delirium (OR 0.28) and cognitive decline (OR 0.38), with a modest reduction in ICU stay.⁵⁰ Similar benefits were observed in older adults undergoing noncardiac surgery, where regional oxygen saturation-guided management reduced postoperative cognitive dysfunction (OR 0.44) and shortened hospital stay.⁵¹

In a recent meta-analysis of cardiopulmonary bypass, goal-directed perfusion strategies targeting avoidance of critical nadir DO₂ were associated with a lower incidence of acute kidney injury (RR 0.52), reinforcing that maintaining perfusion-related oxygen delivery targets protects organ function when anaemia and haemodilution are expected.⁵²

PBM IN SPECIAL POPULATIONS AND HIGH-RISK SETTINGS

Across high-risk populations, implementation of PBM as a three-pillar bundle is consistently associated with improved postoperative outcomes and reduced exposure to allogeneic blood. In trauma, structured PBM algorithms are associated with lower early mortality, reduced plasma and platelet use, fewer massive transfusions, and less blood product wastage compared with ratio-based strategies alone. Pharmacological blood-sparing further improves outcomes; in the CRASH-3 trial, early TXA reduced head injury-related death in patients with mild to moderate traumatic brain injury (RR 0.78) without increasing thrombotic events. Similarly, fibrinogen-centred strategies and structured use of coagulation factor concentrates within goal-directed pathways reduce transfusion exposure and bleeding-related complications in severe bleeding.⁵³

In obstetrics, a staged obstetric PBM program for major haemorrhage (n = 353) reduced mean blood products per admission from 4.18 to 0.67 units (RBC/fresh frozen plasma/platelets combined; p-trend < 0.001), lowered predelivery anaemia from 40.3% to 23.8%, and increased the Hb rise at 3 weeks postdischarge (2.41 → 4.26 g/dL) without worsening composite morbidity or length of stay.⁵⁴ In elderly hip-fracture surgery, a PBM bundle that explicitly included rapid anaemia treatment (IV iron), blood-sparing measures, and restrictive transfusion decision support reduced perioperative RBC transfusion from 43.5% to 33.2%, shortened median hospital stay from 14 to 9 days, and reduced 30-day readmissions from 22.2% to 10.0%.⁵⁵

In colorectal cancer surgery (n = 2080), PBM implementation halved transfusion rates, improved transfusion appropriateness, reduced anastomotic leak rates, and shortened length of stay without increasing overall complications, reinforcing the

effectiveness of PBM bundles across diverse, high-risk surgical populations.⁵⁶

Jehovah's Witness (JW) patients decline transfusion of major blood components; therefore, perioperative care should prioritise informed consent, early planning, and respect for patient autonomy. This population illustrates the practical value of applying a bundled PBM strategy. A 2024 meta-analysis in cardiac surgery suggests that "bloodless" pathways can achieve early outcomes comparable to non-JW cohorts when PBM principles are applied consistently.⁵⁷ Preoperative documentation of which plasma-derived fractions (e.g., albumin or coagulation factor concentrates), and autologous techniques are acceptable to the individual patient is essential, enabling teams to deliver safe and patient-centred surgery.⁵⁸

SUMMARY

Robust evidence now establishes PBM as a core standard of modern perioperative care. Across diverse surgical populations, integrated application of its three pillars reduces transfusion, complications, length of stay, and costs while improving patient outcomes and, in selected settings, survival. PBM offers a pragmatic, evidence-based framework to optimise surgical outcomes while preserving scarce blood resources and supporting sustainable healthcare systems worldwide.

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