Blood loss management in major elective orthopaedic surgery

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Abstract

Blood loss is anticipated with all surgical procedures. Within the field of elective orthopaedic surgery it is especially important to reduce bleeding to maintain a patient's haemodynamic balance and ensure a clear surgical field. Complex reconstructive arthroplasty and spinal procedures can be complicated by significant intraoperative blood loss (IBL) and result in the need for allogenic blood transfusion. Patients with higher rates of IBL have increased blood transfusion requirements, resulting in a higher risk of mortality and significant postoperative morbidity. The aim of this review is to outline strategies to manage IBL for both paediatric and adult patients undergoing major elective orthopaedic surgery, and to evaluate the available evidence regarding their efficacy in managing IBL and reducing the need for perioperative allogenic transfusion.

Keywords arthroplasty; blood; elective; haemorrhage; orthopaedic; spinal; surgery

Introduction

Substantial blood loss may occur during major elective orthopaedic surgery, particularly during hip and knee arthroplasty, spine surgery, and revision surgery. Significant intraoperative blood loss (IBL) may result in physiological fluid shifts, coagulopathies, antibiotic dilution and the need for allogenic blood transfusion.[1] During surgery it is especially important to reduce bleeding in order to maintain a patient's haemodynamic balance and ensure a clear field of view. Limiting blood loss is critically important to minimize patient morbidity and mortality following major surgery.[2] Several interventions have been proposed to reduce the risk of IBL and the need for transfusion of blood products. The impact of these interventions remains controversial and the level of evidence for the efficacy of these methods is limited. This review outlines factors contributing to IBL for both paediatric and adult patients undergoing major elective orthopaedic surgery and reviews the evidence for strategies and techniques to reduce the risk of IBL and perioperative allogenic transfusion.

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Blood loss in hip and knee arthroplasty

Total knee arthroplasty (TKA) is the most common major elective orthopaedic surgery performed worldwide. It has been reported that TKA may result in blood loss necessitating allogenic blood transfusion in up to 10–38% of patients.[3,4] Preventing blood loss around the knee during TKA also minimizes associated haemarthrosis, limb swelling, postoperative pain and use of analgesics. Optimizing these outcomes facilitates better functional rehabilitation during the early postoperative period and improves patient satisfaction. In total hip arthroplasty (THA), the posterior approach requires less operative time and has been associated with reduced blood loss.[5,6] Epidural anaesthesia has also been associated with reduced IBL compared with general anaesthesia during THA.[6] There is a wide variation in the practice of allogenic blood transfusion following primary total hip or knee arthroplasty in the UK.[7] Meticulous haemostasis remains the most important technique for eliminating complications related to perioperative blood loss, and is associated with improved postoperative outcomes.[8]

Blood loss in paediatric spine surgery

The underlying disorder in paediatric deformity surgery plays a major role in determining the extent of IBL. The risk of significant IBL is often higher in patients with neuromuscular disorders undergoing spine surgery compared to patients with idiopathic scoliosis.[9] For patients with a neuromuscular disorder undergoing major spine surgery the mean IBL increases in relation to the underlying diagnosis from cerebral palsy (CP) to spina bifida (SB) and Duchenne muscular dystrophy (DMD). Posterior spinal fusion (PSF) tends to result in greater blood loss than anterior spinal procedures. This blood loss is proportional to the number of vertebral levels involved in the planned spinal fusion.[9] Increasing surgical time is also associated with increasing IBL; during PSF the mean IBL has been estimated to be 500 ml after 2 hours, 1500 ml after 3 hours, and 2400 ml after 4.5 hours of surgery. A PSF when autologous iliac crest bone graft (ICBG) is harvested has been associated with 1828 ml blood loss compared to 1120 ml when ICBG was not harvested. A study of 3119 patients undergoing surgery for spinal deformity assessed the mean IBL proportional to weight; this was estimated at 9.8 ml/kg for adolescent idiopathic scoliosis (AIS), 14.1 m1/kg for CP/SB/spinal muscular atrophy (SMA), and 29.3 ml/kg for DMD (Table 1).[10]

Blood loss in adult spine surgery

Adult patients undergoing major spine surgery, ranging from simple decompressive operations to multilevel fusion surgery, have been estimated to have a mean IBL of 960 ± 730 ml.[11] Significant blood loss may lead to physiological fluid shifts, impaired end-organ perfusion and necessitates the transfusion of allogenic blood products that may impair host immunity and

Estimated blood loss during fusion surgery for spinal deformity

Adolescent idiopathic scoliosis (AIS)	Cerebral palsy (CP)	Neuromuscular disorders (NM)	Spina bifida (SB)	Duchenne muscular dystrophy (DMD)
PSF 750–1500 ml (9–12 levels)	PSF 1300–2200 ml (13–15 levels)	PSF 2000–3500 ml	PSF 1960 ml	930–4000 ml (upper thoracic to sacrum)
ASF 350–650 ml (4–7 levels)	ASF 900–1800 ml (5–7 levels)	ASF 1000–1800 ml	ASF 800 ml	
PSF 60–135 ml per level ASF 65–150 ml per level	CP 100–190 ml per level			DMD 200–280 ml per level

PSF, posterior spinal fusion; ASF, anterior spinal fusion.

Table 1

increase the perioperative risk of infection. Allogenic blood transfusion is estimated to increase patients' risk of significant perioperative bacterial infection by 35% compared with patients that do not receive a transfusion.[12]

Intraoperative blood loss for adults undergoing spine surgery may vary for several reasons (Table 2). During posterior exposure of the spine the paraspinal muscles may have fatty infiltration with vascular engorgement, leading to an increased risk of bleeding when performing subperiosteal exposure. Adults have a relatively thin periosteum and may be osteoporotic with wider vascular channels. Patients requiring decompression of the vertebral canal are also at greater risk of epidural bleeding. The adult spine is also more rigid due to progressive degenerative changes and may require more extensive osteotomies in order to achieve correction of deformity, which increases bleeding from resected bone surfaces. Similar to the paediatric population, fusion of a greater number of vertebral levels is associated with greater IBL.[13] Anaesthesia for adults undergoing major spine surgery may be challenging due to the presence of medical co-morbidities such as hypertension, ischaemic heart disease and peripheral vascular disease; these conditions can preclude the use of systemic methods of reducing IBL such as controlled hypotension.

The risk of requiring a blood transfusion is low for patients undergoing laminectomy alone[14]; only 20% of these patients who auto-donated blood preoperatively used their donated blood. For PSF involving up to three vertebral levels, the incidence of adult patients requiring blood transfusion was 25% for uninstrumented fusions [estimated blood loss (EBL) 674 ± 443 ml], and 50% for instrumented fusions (EBL 1257 ± 793 ml). The most important variables predictive of increased risk of IBL were preoperative haemoglobin level, and the diagnosis of a neoplastic process.[15]

Estimated blood loss for adult spinal procedures

Spinal procedure	Estimated blood loss
Discectomy/decompression	373 ml (100–900)
1–3 level fusion[72]	800 ml (360–3100)
ASF and PSF	1122 ml (700–4000)
Revision lumbar spine	1325–4700 ml
Metastatic thoracolumbar spine tumour	1696 ml

ASF, anterior spinal fusion; PSF, posterior spinal fusion.

Table 2

Blood-sparing strategies

Blood-sparing strategies may be categorized into those aimed at reducing bleeding and those aimed at decreasing the risk of allogenic blood transfusion (Table 3).[16]

Acute normovolaemic haemodilution

Acute normovolaemic haemodiluiton (NH) involves collecting venous blood after the induction of anaesthesia and replacing the lost volume with colloid or crystalloid solution.[17] The aim is to reduce the haematocrit to approximately 0.30 litres/litre (for patients aged under 20 years). Tissue oxygenation is maintained by compensatory increased cardiac output, while venous return may improve due to the decreased viscosity of the circulating blood.[17] NH results in decreased loss of red blood cells (RBCs) in each millilitre of the blood lost intraoperatively. Blood lost during surgery can be collected and re-transfused postoperatively to replenish the haemoglobin level as required. An allogenic blood transfusion rate of 10% has been reported when NH and autologous cell salvage are utilised during major spine surgery.[18] NH has also been suggested as a safe method to meet the perioperative transfusion requirements for adolescents undergoing extensive spinal surgery and, in combination with controlled hypotension and cell salvage, NH has demonstrated reduction in the overall requirement for allogenic blood transfusions (Table 4).[19] However, the literature is conflicting regarding the overall benefits and risks of NH for patients undergoing THA or TKA, and NH may lead to an increase in blood loss following TKA.[20,21]

Planned preoperative autologous donation and erythropoietin treatment

Erythropoietin (EPO) is a hormone produced by the kidney that promotes the formation of RBCs by the bone marrow. Recombinant EPO is indicated for the reduction of allogenic blood transfusion in anaemic patients with a haemoglobin level of 10–13 g/dl, who are scheduled to undergo elective, non-cardiac, non-vascular surgery with significant anticipated blood loss. This was established by four large studies involving major elective orthopaedic surgery.[22–25]

Blood sparing strategies and techniques in spinal surgery

Decrease bleeding	Decrease risk of allogeneic blood transfusion
Patient positioning	Acute normovolaemic dilution
Intrathecal morphine	Planned autologous transfusion and EPO
Controlled hypotensive anaesthesia	Lost blood cell salvage
Local vasoconstriction	
Epidural blockage	
Tumour embolisation	
Systemic agents	
Drugs acting on coagulation	*Drugs not acting on coagulation*
Tranexamic acid (TXA)	Sevoflurane
Epsilon-aminocaproic acid (EACA)	Propofol
Aprotinin	Magnesium sulphate
Local agents	
Bone wax	
Haemostatic sponges (gelatin, collagen, cellulose)	
Fibrin sealants	
Thermal	
Mechanical	

EPO, erythropoeitin.

Table 3

A randomized controlled trial (RCT) involving 48 patients undergoing multilevel ASF and PSF demonstrated that 25% of patients receiving recombinant EPO and performing autologous blood donation preoperatively required allogenic blood transfusion, compared to 85% of patients receiving placebo and performing autologous donation.[26] The minimum effective dosage for recombinant EPO has been shown to be 50 units/kg.[27] There is conflicting evidence regarding the risk of deep vein thrombosis (DVT) and pulmonary embolism (PE) with major orthopaedic surgery following the use of EPO.[22–25] One multicentre RCT studied 680 patients undergoing major spine surgery to evaluate the risk of DVT and PE with recombinant EPO compared to standard of care in spine surgery; there was a higher incidence of DVT (4.7% vs 2.1%), but no increased incidence of PE, associated with EPO treatment.[28] Preoperative autologous blood donation is not advantageous for patients undergoing THA or TKA.[29]

Lost blood salvage

Cell salvage techniques involve collecting IBL though a pump filtration system, washing with a heparinized saline solution and then auto-transfusing this blood to the patient. This 'salvaged' blood does not contain platelets or coagulation factors. Transfusion of allogenic blood products may still be required, as significant auto-transfusion (four units or more) may require supplementation with fresh frozen plasma and platelets. Cell salvage techniques are estimated to recover up to half of the red blood cells lost through bleeding.[30] There is a risk of developing dilutional or disseminated coagulopathy with significant auto-transfusion. Cell salvage techniques are therefore contraindicated in patients with pre-existing coagulopathies. A Cochrane systematic review reported that cell salvage is effective in reducing the need for allogenic blood transfusion and reported an overall 21% absolute risk reduction.[31,32]

Postoperative blood salvage has also been described in several surgical fields. The most common technique involves re-infusion of unwashed blood from wound drainage systems. Evaluating this technique in 150 patients undergoing spinal surgery, one study demonstrated an additional 33% reduction in the need for allogenic blood transfusion when postoperative blood salvage was used, in addition to the benefits of intraoperative cell salvage. The authors noted that greater than 15% of total blood volume (TBV) re-transfusion from postoperative blood salvage was associated with a risk of renal injury due to elevated serum haptoglobin concentration.[33]

Selected articles for acute normovolaemic haemodilution

Author and year	Study design	Patients	Outcome	Results
Oga (1992)[18]	Cohort	101 (48 scoliosis correction; 53 other spine procedures)	Allogenic blood transfusion	10% allogenic blood transfusion rate with NH
Hur (1992)[72]	Case-control	119 spinal fusions with NH; 29 spinal fusions without NH	Allogenic blood transfusion	3.4% allogenic blood transfusion rate with NH; 86% allogenic blood transfusion rate without NH
Copley (1999)[19]	RCT	86 (43 scoliosis correction with NH; 43 scoliosis correction without NH)	Allogenic blood transfusion	37% allogenic blood transfusion rate with NH; 79% allogenic blood transfusion rate without NH
Epstein (2006)[73]	Cohort	68 spinal fusions with NH	Allogenic blood transfusion	23.5% allogenic blood transfusion rate with NH

NH, acute normovolaemic haemodilution; RCT, randomized controlled trial.

Table 4

Transfusion thresholds

Selection of thresholds for allogeneic blood transfusion should include assessment of indiviudal patient's medical co-morbidities and physiological response to blood loss. Restrictive transfusion thresholds of 7–8 g/dl have been demonstrated to be safe in patients without significant medical comorbidities.[34,35] Physiological changes that may indicate the need for transfusion include tachycardia, hypotension, high oxygen requirements, reduced venous oxygen pressure, elevated lactate and electrocardiogram changes indicative of ischaemia. Evaluating the need for transfusion should also include an assessment of the level of shock, haemodynamic compromise, and absolute blood loss. Thrombelastography (ROTEM) can be used to provide immediate assessment of coagulation and clotting and permit informed and focused transfusion of appropriate clotting factors and blood products.[36] Furthermore, physiological body temperature must be maintained, as hypothermia exacerbates blood loss; a decrease of 1.5°C is associated with 50% greater blood loss during THA.[37]

Patient positioning

The epidural veins communicate with the inferior vena cava (IVC) through a valveless system. During prone positioning for spine surgery, the abdomen should be free in order to avoid pressure on the IVC and prevent epidural vein engorgement resulting in operative site bleeding. Furthermore, hypotensive anaesthesia does not affect vena caval pressure after positioning.[38]

Intrathecal morphine

An RCT of patients undergoing surgery for idiopathic scoliosis demonstrated that a 2 μg/kg dose of intrathecal morphine led to a 50% reduction in EBL without affecting neuromonitoring by recording somatosensory evoked potentials.[39]

Controlled hypotensive anaesthesia

Controlled hypotension has been established practice in orthopaedic surgery since the 1950s.[40] The overall goal is to maintain a mean arterial pressure (MAP) of 40–50 mmHg or a systolic blood pressure less than, or equal to, 80 mmHg. In addition to lowering blood pressure and thereby lowering extravasation of blood directly from the tissues, it serves to reduce the thrombus dislodgement that occurs at a systolic pressure greater than 80 mmHg. Dilution of coagulation factors inhibits further clot formation, which is aggravated by the presence of hypothermia.[41] Hypotensive anaesthesia is contraindicated in patients with pre-existing hypertension, ischaemic heart disease or peripheral vascular disease and should be used judiciously in elderly patients. The effect of hypotensive anaesthesia does not directly appear to increase the risk of neurological damage to the spinal cord during spine surgery. Studies have demonstrated that evoked potential neuromonitoring shows temporary alterations but no permanent damage.[42]

Local vasoconstrictors

Local infiltration of vasoconstrictors, such as adrenaline, is widely used to reduce bleeding during surgical exposures. Infiltration can either be with adrenaline alone or mixed with lignocaine/chirocaine. This aims to decrease local blood flow and reduce subsequent blood loss.[43] Injection prior to wound closure can be performed during hip and knee arthroplasty and may reduce postoperative bleeding, but has not been shown to alter the need for blood transfusion.[44]

Epidural blockade

Epidural blockade is performed by administering a caudal epidural injection of bupivicaine (e.g. 2 ml of 0.25% bupivicaine) prior to surgery and can reduce intraosseous pressure through local sympathetic blockade.[45] This results from increased blood flow in the pelvis and lower limbs due to venous pooling distant from the operative site. This promotes relative venous hypotension in the epidural venous plexus and bony vertebral structures. In a case–control study of elective cervical and lumbar spine surgical procedures, epidural blockade was associated with reduced blood loss in surgical procedures involving the lumbar spine, but not the cervical or upper thoracic spine.[45]

Tumour embolization

IBL and perioperative transfusion can be reduced by preoperative embolization for patients with metastatic and primary bone tumours. Embolization for metastases, particularly from renal cell tumours and thryroid carcinoma, results in both reduced blood loss and transfusion requirements.[46] Surgical resection of tumours may be performed 13–24 hours following embolization therapy. However, no difference in blood loss has been demonstrated when embolization is performed for metastases secondary to primary breast, lung, or prostate malignancy.[47] Histoacryl is an acrylic glue that may be effectively used in the percutaneous treatment of spinal aneurysmal bone cysts (ABCs), and which has also been injected into vertebrae preoperatively to reduce the risk of bleeding during surgical resection of malignant tumours.[48,49]

Systemic agents

Several pharmacological and topical agents have been evaluated for their impact on IBL during orthopaedic surgery; these may act directly on the coagulation system, or have a remote mechanism of action.

Drugs acting on the coagulation system

Tranexamic acid (TXA)

TXA is a synthetic lysine analogue derivative that inhibits fibrinolysis. It competitively inhibits the conversion of plasminogen into plasmin. Plasmin is responsible for the degradation of fibrin. TXA has been shown to be highly effective in reducing blood loss during elective hip and knee arthroplasty surgery (Table 5).[50,51] A standard dose of TXA may reduce blood loss during posterior cervical and lumbar spine surgery by 25% and 13%, respectively. High-dose TXA (comprising a loading dose of 100 mg/kg followed by a continuous infusion of 10 mg/kg/hour) can achieve even greater improvement in blood loss (39.8%).[52]

Epsilon-aminocaproic acid (EACA)

EACA is an antifibrinolytic agent that also prevents plasmin from binding to fibrin. Several RCTs have demonstrated that EACA is highly effective in reducing perioperative blood loss and transfusion requirements associated with complex spine deformity surgery, and that EACA is associated with a 30% reduction in

Selected articles for tranexamic acid

Author and year	Study design	Patients	Outcome	Results
Elwatidy (2008)[74]	RCT	64	IBL, transfusion	Patients who received TXA had 49% reduction in blood loss and 80% reduction in blood transfusion, and shorter hospital stay
Farrokhi (2011)[75]	RCT	76	IBL, transfusion	No statistical difference between groups for IBL and transfusion
Tsutsumimoto (2011)[76]	RCT	40 — posterior cervical and lumar decompression	IBL, PBL	No statistical difference in IBL with TXA use. PBL during first 16 h was reduced by 37% in TXA group. Total blood loss in first 40 hours significantly reduced.
Wang (2013)[77]	RCT	60 — posterior cervical and lumbar decompression	IBL, PBL	No differences in IBL, but significantly lower PBL in TXA group
Xie (2015)[52]	Retrospective	50 — saline control (33), high dose TXA (26)	IBL, blood transfusion	IBL in TXA group statistically lower
Seddighi (2017)[78]	RCT	40	IBL, PBL	Significantly lower IBL and PBL in TXA group

RCT, randomized controlled trial; IBL, intraoperative blood loss; PBL, perioperative blood loss; TBL, total blood loss; TXA, tranexamic acid.

Table 5

postoperative transfusion requirements for patients undergoing major reconstructive spinal surgery.[53,54] Rare complications have been associated with its use, including DVT, PE, renal failure and severe bradycardia. A Cochrane systematic review supported the use of EACA as an antifibrinolytic treatment during surgery.[55]

Aprotinin

Aprotinin is a serine protease inhibitor. Aprotinin prevents fibrinolysis by inhibiting plasmin, trypsin and kallikrein. It also prevents platelet activation by stabilizing the platelet membrane and decreases the inflammatory response by inhibiting bradykinin, interleukin and TNF. One RCT reported that aprotinin significantly decreases blood loss and transfusion requirements in pediatric and adolescent scoliosis surgical patients at increased risk for IBL.[56] Aprotinin therapy has also been associated with reduced blood loss in paediatric neuromuscular scoliosis surgery.[57] However, caution is required in relation to aprotinin therapy, as it has been associated with hypercoagulability, increased thrombus formation, and renal dysfunction, and there is a risk of rare anaphylactic-type reactions following previous administration and sensitization.[56,58]

Drugs to manage blood loss acting outwith the coagulation system

In a prospective study, patients (n = 28) undergoing lumbar spine surgery were randomized to hypotensive anaesthesia with propofol or sevoflurane, with a target 15% reduction in MAP from baseline.[59] Blood loss was significantly greater in the sevoflurane group (mean 315 ± 99 ml) compared to the propofol group (mean 106 ± 59 ml). There are no studies investigating the inclusion of a muscle relaxant such as atracurium, rocuronium or vecuronium on the effects of IBL in spine surgery. Administation of muscle relaxant may ease surgical exposure and reduce IBL by inhibiting muscle contractions and preventing bleeding at the operative site. Magnesium sulphate has also been associated with reduced blood loss during single level microdiscectomy surgery in a single RCT.[60]

Topical agents to control blood loss

Bone wax

Bone wax is a mixture of beeswax, paraffin and isopropyl palmitate. Bone wax acts to fill and block sites of bleeding at bone surfaces. Although bone wax is considered relatively inert, one case has been reported of tetraplegia due to the use of bone wax resulting in direct cervical cord compression.[61] Its use during TKA has been associated with reduced blood loss.[62]

Haemostatic sponges

Gelatin-based local haemostatic agents (e.g. Gelfoam®, Surgifoam®) can be categorized according to their tissue of origin; they may be derived from bovine, porcine or equine tissue. They may be reconstituted and are available in different forms including sheets, powders, or foam. They provide a surface template to facilitate clot aggregation and formation at bleeding sites. Collagen sponges are inferior to gelatin or alginate scaffolds in stabilising clot formation.[63] Although haemostatic sponges are usually safe when applied topically, complications associated with use of gelatin-based agents include:

1. Quadriparesis after cervical decompression and fusion[64]
2. Lumbar laminectomy and gelatin foam-induced monoradiculopathy[65]
3. Lumbar cauda equina syndrome due to retained gelatin foam following decompression for stenosis[66]
4. Allergy following gelatin foam[67]

Collagen-based agents (e.g. Lyostypt®) provide a surface to promote platelet aggregation by activating factor XII and they induce fibrinogen polymerization. They may be used in powder, sheet, or gauze forms. These agents may provoke

adhesions and foreign body reactions and thus should not be left *in situ*.

Fibrin sealants

Fibrin sealants act on the late phase of the coagulation cascade and promote the formation of a fibrin clot. A Cochrane systematic review of the use of fibrin sealants in surgery concluded that their use is associated with reduced blood loss and reduced risk of allogenic blood transfusion.[31] There are two main types of fibrin sealant:

1. Fibrinogen component and thrombin solution (e.g. Tisseel®, Haemaseel™, CoStasis®). These adhere poorly on wet or bleeding surfaces and may also contain TXA or aprotinin. The use of bovine fibrinogen has been withdrawn due to the risk of encephalitis. CoStasis® uses the patient's centrifuged plasma with bovine thrombin, avoiding the use of bovine fibrinogen.
2. Thrombin solution that utilises fibrinogen from the bleeding sites (e.g. FloSeal®). These sealants comprise collagen and thrombin in a gel matrix and depend entirely upon fibrinogen from the surgical site. Swelling of collagen granules restricts bleeding through a direct tamping effect. The gelatin matrix provides structural stability. The main advantage of this type of fibrin sealant is their ease of use on wet and bleeding tissues intraoperatively.

Mechanical

The use of tourniquet to control blood loss during total knee arthroplasty remains controversial. A meta-analysis reported that early release of the tourniquet during TKA may increase the blood loss, but may decrease the incidence of further complications such as wound inflammation and necrosis, and superficial or deep wound infection; the routine use of tourniquets during total knee arthroplasty could not be recommended.[68] Furthermore, the routine use of surgical site drains lacks efficacy in preventing blood loss and reducing transfusion rates.[69]

Direct pressure can be effective in controlling bleeding. Direct digital pressure can be applied at the entry point during preparation of pedicle tracts prior to pedicle screw insertion in order to minimise bleeding. Alternatively, fibrin sealants may also be used to control bleeding from pedicle tracts prior to final screw insertion. Neither the use of compression bandaging nor cryotherapy reduce blood loss following TKA.[70,71]

Thermal

Electrocautery in the form of either monopolar of bipolar diathermy is useful and effective for controlling bleeding sites but not for diffuse capillary bleeding. Vertebral canal and foraminal bleeding sites can be controlled with the use of bipolar cautery to prevent thermal damage to adjacent neural tissues.

Conclusion

Significant blood loss may be anticipated during complex or revision hip and knee arthroplasty or major spinal surgery. Optimising the preoperative haemoglobin and meticulous attention to controlling intraoperative blood loss are the most important strategies in reducing the need for perioperative transfusion of blood products. During elective spine surgery, increasing number of vertebral levels for fusion and surgical time are associated with increased blood loss, as are patient comorbidities including neuromuscular disorders, osteoporosis, ischaemic heart disease, and peripheral vascular disease. The strategies and techniques discussed within this article should be employed judiciously to minimize perioperative blood loss, reduce the need for allogenic blood transfusion, reduce perioperative morbidity, and improve patient outcomes following major elective orthopaedic surgery. ◆

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