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REVIEW ARTICLE

Alternative Procedures for Reducing Allogeneic Blood Transfusion in Elective Orthopedic Surgery

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Abstract Perioperative blood loss is a major problem in elective orthopedic surgery. Allogeneic transfusion is the standard treatment for perioperative blood loss resulting in low postoperative hemoglobin, but it has a number of well-recognized risks, complications, and costs. Alternatives to allogeneic blood transfusion include preoperative autologous donation and intraoperative salvage with postoperative autotransfusion. Orthopedic surgeons are often unaware of the different pre- and intraoperative possibilities of reducing blood loss and leave the management of coagulation and use of blood products completely to the anesthesiologists. The goal of this review is to compare alternatives to allogeneic blood transfusion from an orthopedic and anesthesia point of view focusing on estimated costs and acceptance by both parties.

Keywords allogeneic blood transfusion · blood loss · elective orthopedic surgery · autologous blood transfusion · predonation · hemodilution · EPO · iv iron · fibrin sealant · platelet gel

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Introduction

Perioperative blood loss is still a major problem in elective orthopedic surgery. Allogeneic blood transfusion is the standard approach to treat potentially detrimental decreases in hemoglobin (Hb) concentration. Inherent risks in homologous transfusions persist despite all efforts to avoid them. In addition to well-known risks, such as the transmission of infections (Table 1), transfusion febrile reactions [22], or transfusion-related acute lung injury [52], there is some concern about a causal relationship between allogeneic red blood cell (RBC) transfusions and immunomodulation. Immunomodulation is an allogeneic blood transfusion related immunosuppression, which is thought to increase the incidence of postoperative infections (up to six times), delay healing of postoperative wounds, and thereby prolong hospitalization [7, 8, 24, 45, 74, 90–92].

Another disadvantage of allogeneic blood transfusions is the cost. Reported cost per unit of packed red cells has varied between $270 and $780, depending on further costs for storage, laboratory analyses (cross match tests, antibody tests, etc.), and other postdonation processing. Actual figures in Switzerland show that the cost for one RBC unit in surgery is $500, without taking into consideration transfusion-related complications [78].

In view of the possibility that public health systems may face an exponential cost increase for transfusion medicine in the near future [37, 94], it is the goal of this review article to compare several alternatives to allogeneic blood transfusion. Although many review articles have dealt with this issue, most of them either do not account for most of the alternatives, do not include cost estimations, or consist only of expert opinions. Special attention is paid therefore to the cost of the alternatives, as well as the surgery-specific drawbacks of each and the acceptability to orthopedic surgeons.

While the experience and skills of the surgeon are probably the most important factors influencing intraoperative blood loss [46, 66], it is also the one factor that cannot be managed by any other team member. Adequate hemo-

Table 1 Incidences of potential risks associated with allogeneic blood transfusions (adapted from Pape et al.)

Risks associated		Incidence	References
Volume overload	Hypertension, pulmonary edema	1:100–1:1,000	[30]
Mistransfusion	Acute hemolytic reaction	1:6,000–1:33,000	[39]
	Delayed hemolytic reaction	1:2,000–1:11,000	[39]
Bacterial contamination	Sepsis	1:10,000–1:100,000	[30]
Viral contamination	HIV	1:2,300,000	[23]
	Hepatitis C	1:1,800,000	[23]
	Hepatitis B	1:350,000	[23]
	Hepatitis A	1:1,000,000	[71]
	Cytomegalovirus	1:10–1:30	[71]
	Epstein–Barr virus	1:200	[71]
	West–Nile virus	1:3,000–1:5,000	[39]
Prion contamination	Creutzfeldt–Jakob disease	Unknown	[23]
Transfusion-related acute lung injury	Immune	1:625	[30]
	Nonimmune	1:2,800	[30]
Allergic transfusion reaction		1:100–1:2,000	[30, 71]
Immunosuppression		1:1	[71]
Alloimmunization		1:16,000	[71]

stasis therefore remains the "gold standard" technique for eliminating potential complications related to blood loss. Its impact on transfusion rates is obvious: Blood that is not lost does not have to be replaced.

Alternatives to allogeneic blood transfusions

Several methods and approaches have been described to reduce allogeneic blood transfusions in orthopedic surgery. These include modifications of the indications for transfusion (transfusion triggers) based on Hb concentration, predonation of autologous blood, iron substitution, erythropoietin (EPO) injections, adjustment of perioperative medication (anticoagulation, nonsteroidal anti-inflammatory drugs (NSAID)), body temperature adjustments, goal-directed transfusions, hypotensive epidural anesthesia, normovolemic hemodilution, application of platelet gel/fibrin gel to the surgical site, and intraoperative capture and transfusion of lost autologous blood (Cell Saver/C.A.T.S. and ABT/Bellovac). Each alternative to allogeneic blood transfusion has its pros and cons, and in this review, we describe these in detail.

Adjusting the indications for transfusion

One method to reduce the use of allogeneic transfusion is to adjust or modify the indications that are based on measured hemoglobin and hematocrit levels. Despite extensive physiological data, indications for RBC transfusion are not uniform. Until the 1980s, many transfusion protocols used the 10/30 rule, which held that hemoglobin must exceed 10 g/dl and hematocrit should be higher than 30% before operation. This recommendation was later applied to all transfusion settings, acute or chronic, and led to the choice of Hb 10 g/dl as the threshold at which transfusion was felt to be indicated [51]. According to current guidelines from the American Society of Anesthesiologists, RBC transfusion is recommended if the hemoglobin concentration drops below 6–10 g/dl. Transfusions over 10 g/dl are rarely indicated, and transfusions are generally indicated if hemoglobin falls below 6 g/dl. In Europe, a target range of 7–9 g/dl is largely accepted, even in major trauma [60].

Hemoglobin levels below 6.4 g/dl have been associated with impaired cognitive function. Hemoglobin levels below 4.8 g/dl are associated with a mortality of 50% and are therefore not recommended [97]. Hemoglobin levels alone, however, do not always justify transfusion. Multiple clinical factors and hemodynamic parameters should be evaluated in every case [58], and allogeneic transfusion decisions should be individualized [85].

Physiological transfusion triggers include tachycardia, hypotension, oxygen extraction greater than 50%, mixed venous oxygen pressure of less than 32 mmHg, increase of lactate, and electrocardiography changes. The severity of shock, hemodynamic response to resuscitation, and the rate of actual blood loss in the acutely bleeding and hemodynamically unstable patient may also be taken into consideration. However, RBC transfusions should be used sparingly during elective orthopedic surgery.

Given the transfusion triggers that are currently accepted in clinical practice, it appears that clinical outcomes could improve significantly with more widespread adoption of restrictive transfusion strategies [25]. The exception to this approach should include elderly patients with significant comorbidities that increase the risk of complications from a low hemoglobin. If restriction of transfusion alone is used, the costs for packed red cells can be decreased, but the result may include symptomatic patient weakness, prolonged hospital stay, and delayed rehabilitation [14]. In addition, treating surgeons may be hesitant to observe patients with low Hb levels, hoping to avoid complications associated with postoperative anemia. Additionally, the surgeon becomes vulnerable from a liability standpoint if transfusion below a threshold of 10 g/dl is deemed to be "standard of care" and he decides to observe rather than transfuse. Therefore, a better approach would include optimal patient preparation prior to elective surgery to reduce the need for allogeneic transfusion, while avoiding the problems associated with symptomatically reduced red cell mass [14].

Autologous blood donation

Autologous blood donation has been proposed as a method to help avoid the need for allogeneic transfusion in the perioperative period. This method is used 4–6 weeks in advance of elective surgery in patients who have an expected intraoperative blood loss of more than 1.5 l. Patients donate one or more units of autologous blood preoperatively. A recovery period of about 4 weeks is required prior to surgery. The units are stored in a blood bank until they are needed. The units can either be transfused preoperatively (not later than 72 h before surgery) [93] or kept refrigerated in case of postoperative need. Blood bank handling is similar to that of allogeneic blood. Contraindications to predonation include cardiac risks such as unstable angina, myocardial infarction within the previous 3 months, coronary artery stenosis involving the left coronary artery, congestive heart failure, and significant aortic valve stenosis with an Aa gradient > 70 mmHg [49].

The existing literature regarding predonation is conflicting. Although several orthopedic trials have reported a possible reduction of the patient's relative risk of receiving an allogeneic blood transfusion when predonation was used [44, 101, 102], several studies have been published which question the routine use of predonation in elective orthopedic surgery [86, 89]. Described risks include transfusion reactions, circulatory volume overload, bacterial contamination, and clerical errors [35]. It is a time-consuming method which can present logistical problems and may lead to wastage up to 45% of donated blood [31, 35]. Predonation has been declining in popularity for elective orthopedic surgery since 2002 [54]. A cost–effectiveness analysis in total hip arthroplasty found no significant difference in complication rate between predonation of autologous blood and allogeneic transfusion [42]. Furthermore, the method is not cost-effective if:

1. At least one unit of allogeneic blood must be transfused despite previous autologous donation
2. More than 15% of the donated blood must be discarded [40]

Preoperative strategies to avoid transfusion

A preoperative strategy that can be used to help avoid the need for postoperative transfusion is intravenous administration of iron. Since iron deficiency anemia is the most common anemia among patients undergoing orthopedic surgery (prevalence of up to 21%) [89], preoperative iron supplementation has been proposed in order to elevate hemoglobin levels [98]. Iron can be supplemented both orally and parenterally, but intravenous administration is five times more effective in inducing the erythropoietic response after significant blood loss [98]. A recent study reported diminished transfusion requirements after abdominal hysterectomy with preoperative intravenous iron administration [21]. In combination with EPO, it has been shown to decrease not only transfusion rate but also infection rate and mortality [16–18]. Although iron therapy has been found to be generally safe and effective, especially high molecular weight iron, dextran has the disadvantage of potentially life-threatening dextran-associated anaphylactic reactions [12]. Recently, a novel intravenous iron preparation of ferric carboxymaltose (FERINJECT®, Vifor Int., St. Gallen, Switzerland) has been developed and is a part of current ongoing trials. It offers the advantage of being well tolerated; however, the possibility of overdose may be an issue [53]. More clinical trials are needed to determine the optimal method of preoperative iron therapy [6].

Iron supplementation and EPO administration work synergistically. Therefore, they are often recommended as combination therapy [15, 19, 38] to maximize effectiveness and minimize suspected risks of thrombosis (with EPO alone) [31] and depletion of endogenous erythropoietin reserves (with iron alone) [89].

The costs for iron therapy depend upon the amount to be given and the cost of the drug. Assuming an average patient requires 1 g of iron, the cost for the treatment with ferric carboxymaltose would be $300. That is expensive but still cheaper than one unit of packed RBCs [78]. Iron supplementation is well accepted by patients and surgeons. A possible disadvantage is the delay between iron administration and the resultant increase in Hb concentration, which makes the method less useful in emergency cases.

Erythropoietin is a glycoprotein hormone, which is mainly produced by the kidneys and that is considered to be the most important regulator of erythropoiesis [27, 47]. EPO increases hematocrit values when given without concurrent phlebotomy for autologous blood donation [3]. Therefore, there is a potential risk of thromboembolic complications from the elevated hematocrit. Therefore, phlebotomy for autologous blood donation is recommended if the hematocrit rises above 50% during EPO therapy to reduce the risk of thrombotic complications [63]. The optimal dosage of EPO prior to elective orthopedic surgery has not been determined. The lowest effective dose described is 100 IU/kg of rHuEpo given twice a week for 2 weeks [75]. Assuming an average patient weighs 70 kg, this treatment would cost about $600. In one study, patients in The Netherlands with preoperative hemoglobin levels between 10 and 13 g/dl received an increased dosage, 600 IU/kg of EPO once a week starting 3 weeks before the scheduled surgery [65]. A high dose of 40,000 IU, given three times preoperatively, has been shown to be extremely efficient but costs about $3,000 [13]. Relative contraindications to EPO administration include personal and familial history of thromboembolic events, severe hypertension, allergy, pregnancy, or breastfeeding.

It is unclear whether the withdrawal of EPO, at the conclusion of therapy, may have any detrimental effects. A process called neocytolysis has been described, in which the rapid fall of EPO levels may negatively influence erythropoiesis [13]. It has not yet been reported upon EPO withdrawal but remains a theoretical concern.

Patients requiring surgery are often on a variety of medications which may impact perioperative blood loss and contribute to the fall in hemoglobin concentration after surgery. Anticoagulation with vitamin K-antagonists or aspirin is important to elicit in the patient's history. It is common to discontinue the use of such agents several days before surgery. However, discontinuation of agents such as clopidogrel and aspirin in patients with unstable coronary perfusion and/or recently implanted stents before elective orthopedic surgery has been reported to result in unacceptably high risks for thromboembolic events [10, 11, 82, 83]. While aspirin is a lifelong therapy, clopidogrel is usually prescribed until the coronary stents are fully endothelialized. This usually takes 6–24 weeks for bare metal stents, but clopidogrel must be taken for 1 year after implantation of drug eluting stents [11]. The hemorrhagic risk with antiplatelet therapy is modest with an estimated 2.5–20% more blood loss with patients continuing aspirin and 30–50% with the combination of aspirin and clopidogrel [11]. Discontinuation or reducing the therapy to aspirin alone would be recommended only when bleeding might occur in a closed space (e.g., intracranial neurosurgery), when an extremely high blood loss (>2 l) is estimated, or when aspirin is only used at a preventative dose (81 versus the 325 mg therapeutic dose) [83].

The use of NSAIDs should also be elicited in the patient's history. It is generally recommended that all NSAIDs should be stopped at least 24 h before surgery. NSAIDs are also widely used for perioperative analgesia and might adversely affect hemostasis. Selective COX 2 inhibitors may not cause impaired platelet aggregation, prolonged bleeding time, and increased intraoperative blood loss, making this class of drug better suited for perioperative pain relief [80, 96].

Perioperative strategies to reduce intraoperative blood loss

Body temperature during surgery can be manipulated to affect intraoperative bleeding. Body temperature has been shown to affect both platelet aggregation and bleeding time. Even slight decreases of body core temperature of only 1.5°C were associated with increased blood loss of about 50% during total hip replacement [76, 99]. Maintenance of physiologic body temperature thus seems to be important for controlling blood loss, and special attention to the patient's core temperature should be paid by the surgical team.

Goal-directed transfusion is another strategy that can be used to help reduce preoperative blood loss and need for allogeneic blood transfusion. The principle of goal-directed transfusion is to optimize the coagulation pathway before a transfusion is given. This is done by replacing essential coagulation factors. Fibrinogen and the prothrombin complex (concentrate of factors II, VII, IX, and X, antithrombin III, protein C) are able to improve coagulation and minimize blood loss [32, 33]. The method can only be applied if coagulation is continuously monitored during surgery by a point-of-care (POC) coagulation monitoring device. Rotation thromboelastometry (ROTEM®, Pentapharm, Munich, Germany) and thromboelastography (TEG®, Hemoscope, Niles, IL, USA) are examples of such devices. These powerful tools can help to determine the causes of hemorrhage. The tests are performed with whole blood which allows conclusions to be made about the whole clotting process, fibrinolysis, and platelet function, with results available quickly at the bedside [34, 57]. In combination with a transfusion algorithm, this has been shown not only to decrease the transfusion requirements during surgery but also to be cost-effective [1, 79, 84]. The Society of Thoracic Surgeons and the Society of Cardiovascular Anesthesiologists both confirm these positive results and recommend the guidance by POC tests for coagulation products [29].

The technique of hypotensive epidural anesthesia (HEA) is not widely performed in orthopedics yet. Nevertheless, it is a readily available and effective method to reduce perioperative blood loss [70]. The aims of this method are to achieve an epidural dermatome block at least as proximal as the T2 level and to establish a dense block of the cardioacceleratory fibers of the thoracic sympathetic chain. Bradycardia is usually prevented by continuous intravenous infusion of a low-dose epinephrine solution. This leads to reduced arterial pressure while heart rate, central venous pressure, stroke volume, and cardiac output are maintained in the normal range. Mean artery blood pressure can be lowered to 50 mmHg resulting in a reduction of intraoperative blood loss of up to 40% [69] and decreased postoperative wound drainage, as seen in several orthopedic trials [26, 48, 87]. HEA seems to be an attractive alternative from a patient's point of view. It is, however, limited to procedures amenable to regional anesthesia and requires an anesthesia team which is comfortable and proficient in administration of HEA.

Normovolemic hemodilution is a procedure in which 2–4 units of whole blood are withdrawn from the patient in the operating theater just prior to the start of surgery and replaced with acellular fluids (e.g., colloids or crystalloids). The advantage of this procedure is that fewer erythrocytes are lost in case of bleeding during the surgical procedure. Additionally, fresh whole blood is instantly available for autologous retransfusion. The procedure has been shown to reduce the need for allogeneic blood transfusion in other surgical specialties [41, 61, 88, 100] as well as in orthopedic surgery [5, 36]. These results could, however, not be confirmed in two meta-analyses [9, 77]. The contraindications for normovolemic hemodilution are severe anemia, hemorrhagic shock related to trauma, active sepsis, respiratory failure, and myocardial insufficiency [67].

Hemodilution is a patient friendly method that is easy to perform. Monk et al. estimated the cost for normovolemic hemodilution at $30, compared with $226 per unit of red blood cells [64]. Hemodilution, especially when hydroxyethyl starch is used as the volume expander, can lead to aspirin-like intraoperative bleeding from capillaries due to reduced platelet aggregation caused by colloids. In procedures where well-controlled hemostasis is necessary, normovolemic hemodilution might not be ideal.

Use of thrombotic agents

The intraoperative use of directly applied thrombotic agents can reduce blood loss and the need for allogeneic blood transfusions. Platelet gel is manufactured from platelet rich plasma which is obtained after the sequestration of autologous whole blood with a blood cell separator. Treatment involves direct application of concentrated platelets and their growth factors, especially platelet-derived growth factor and transforming growth factor-β, which augment the wound healing cascade [68, 72, 103]. Platelet gel is very cost-effective (about $24 per unit of blood sequestered) and efficient in orthopedic surgery. Because of the high concentration of leucocytes and, in particular, granulocytic neutrophils which contain myeloperoxidase (a substance known to remove bacteria), it may be speculated that platelet gel may also have antibacterial properties [56]. Approximately 350 ml of venous blood is collected intraoperatively, processed in a centrifuge, fractioned into blood components, and then sprayed onto the surgical field [28].

Fibrin sealants (also known as fibrin glues) are plasma-derived surgical hemostatic agents. They replicate the final steps of the physiologic coagulation cascade to produce a stable fibrin clot. Generally, two major components are present: fibrinogen (with or without factor XIII) and thrombin (plus calcium with or without antifibrinolytic drugs). Fibrin sealants can be applied to the surface of the wound using a dual syringe system in a liquid or an aerosol form.

The literature clearly shows improved hemostatic effects in both animal and human models [59]. While the efficiency of fibrin sealants is well described in cardiothoracic surgery, cosmetic surgery, and neurosurgery [50, 59], only a few similar clinical studies [55, 95] have been performed in orthopedic surgery using a nonautologous cryoprecipitate-based fibrinogen. In addition to the improved hemostatic effect, a lower incidence of postoperative wound healing disturbances [28], fewer infections, and a shorter length of hospital stay have been described [72]. The costs, however, are not negligible: 1 ml of the glue is used for 10 cm^2 of wound surface, and the price is about $175/ml (Baxter®, Deerfield, IL, USA). The use of these surgical hemostatic agents is not an acceptable replacement for diligent surgical hemostasis [59].

Autologous capture and transfusion

There are basically two approaches to autologous capture and transfusion. The blood can either be washed mechanically before it is given back to the patient (indirect) or it can be filtered before transfusion (direct). Examples for the indirect transfusion systems are the discontinuous autotransfusion system (e.g., “Cell Saver®” system, Haemonetics Corp, Braintree, MA, USA). An example of a continuous autotransfusion system is the CATS, “C.A.T.S.®” system. (Fresenius, Bad Homburg, Germany). In both systems, the blood is centrifuged, dividing the corpuscular elements according to their density, and washed with a physiological liquid (e.g., normal saline) [20]. The difference is that in the discontinuous method, each cycle processes a fully loaded blood reservoir while the continuous system is almost independent of the blood volume after priming the system with a volume of 30 ml. A further advantage of the continuous technique is the smaller centrifugal force used to separate the erythrocytes. Also, there is a higher percentage of removed residual fat particles, which can be relevant especially in orthopedic surgery. The discontinuous system, however, is more consistent in removing leukocytes [20].

The quality of freshly salvaged red blood cells is at least comparable with stored red blood cells [62]. An absolute contraindication to indirect autologous transfusion is bacterial contamination of suctioned blood. Use of such a system in tumor surgery is relatively contraindicated [4]. Intraoperative cell salvage has been proven to be an effective method to avoid allogeneic blood transfusion [81]. Indirect autologous transfusion systems in orthopedic patients can decrease the need for allogeneic blood transfusions from 70% to 23% [43]. Due to high cost (Cell Saver® about $2400, Haemo-

Table 2 Comparison of different alternatives to allogeneic blood transfusion: absolute costs, work load, and efficiency

	Cost	USD	Work load	Efficiency
RBC unit (allogeneic)	0	522–1,183	0	0
Predonation	+	unknown	+	0
EPO	++	3,000	++	−
Iron i.v.	−	150–450	++	−
Hemodilution	−		−	−
Platelet gel	−	175	−	−
Fibrin sealant	−	175	−	−
Direct retransfusion (Cell Saver®)	++	2,400	++	−
Indirect retransfusion (ABT Bellovac®)	−	100	++	−

− less than allogeneic blood transfusion, + more than allogeneic blood transfusion, *0* baseline netics Corp, Braintree, MA, USA) associated with the technique, intraoperative indirect autologous transfusion might be most suitable for complex and revision surgeries.

Another method for replacing shed blood includes reinfusion of postoperative drainage as a form of direct autologous transfusion (e.g., Bellovac ABT®, Astra Tech, Vienna, Austria). Autologous transfusion of filtered postoperative blood loss has gained popularity in the orthopedic community, especially since it is cost-effective and easy to use. Initially, concerns existed about the safety of unwashed, filtered blood, but recent studies [40–42] have maintained that autologous transfusion is safe, provided certain protocols are followed. These protocols include not exceeding maximum transfusion volumes, minimum threshold blood loss over 250 ml, and transfusion within 6 h after surgery, thereby minimizing any hematological or immune reactions [44]. After 6 h post-op, the system is used as a regular vacuum drain.

The development of complement split products and proinflammatory cytokines (especially interleukin (IL)-1, IL-6, and IL-8 and tumor necrosis factor-alpha) in postoperative drainage has also been cause for concern. These agents can possibly lead to hypotension, confusion, cardiac or pulmonary compromise, febrile reactions, coagulopathy, and even death [2]. Nonetheless, several studies show the potential benefits (easy handling and low cost: around $100 along with reduced hospital stay), especially after hip and knee replacement [37, 38, 42, 44, 47, 48]. There are other trials which describe problems with this system [46] and an increase in complication rate of 10% (mostly febrile reactions or tachycardia) [73].

Autologous transfusion of captured blood loss is most effective if all lost blood can be collected and given back. This is the case in total knee arthroplasty, where a tourniquet is used during the operation. In hip arthroplasty, where the significant blood loss occurs during the surgery, this might not be the case [48]. However, several authors have reported a positive effect of the direct autologous transfusion method also after total hip arthroplasty [37, 44, 48].

Conclusions

Concerns about the safety and expense of allogeneic blood have led to increased research and efforts to improve patient blood management in orthopedic surgery. Various techniques have also been developed to minimize the need for autologous blood transfusion.

For example, patients who are anemic preoperatively, combination therapy with i.v. iron and EPO is optimal [15, 19, 38]. Platelet gel and fibrin sealant can be used intraoperatively. In addition to the improved hemostatic effect, proposed benefits include lower incidence of postoperative wound healing disturbances, fewer infections, and a shorter length of hospital stay [18]. Intraoperative salvage has been shown to be effective in patients where predonated blood is unavailable or when excessive blood loss (>1.5 l) is expected [36]. Because of the high cost associated with it, this method should not be used indiscriminately.

Postoperative salvage is still discussed with controversy because of possible side effects. However, most of the concerns could be proven wrong, and the method is inexpensive and easy to use [17, 18, 37, 38, 42, 44, 47, 48].

In summary, many strategies for avoidance of allogeneic blood transfusion are available and are probably underutilized. Some methods are limited to the treating anesthesiologist while others can be applied intraoperatively by the surgeons. Ideally, the strategies and methods applied by each party should work in concert. It is important to know the patient's preoperative hemoglobin level and the expected blood loss and to have some knowledge about the many different alternatives available for reducing the need for allogeneic blood (see Table 2). Transfusion triggers should be applied for all patients in the same way and only be adapted in special cases (e.g., elderly patients, cardiac history). Preoperative anemia has to be detected early to treat patients adequately till surgery (e.g., iv iron, erythropoietin). The intraoperative use of thrombotic agents on the surgical side and blood saving devices (Cell Saver®, Bellovac ABT®) on the anesthesiological side can be used to find an optimal and individual treatment for each patient. Ultimately, each hospital will have to adapt their methods to the type of surgery performed, as well as their financial resources.

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