14 Blood Preservation Strategies in Total Knee and Unicompartmental Knee Arthroplasty

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Introduction

Total knee arthroplasties (TKA) are associated with significant blood loss, ranging up to 1.8 liters in some series [1–5]. This large degree of visible and hidden blood loss can result in various adverse effects including the development of symptomatic anemia requiring blood transfusion in up to 38% of patients [6–9]. Patients undergoing unicompartmental knee arthroplasty (UKA), however, have been shown to have decreased total blood loss and decreased risk of developing symptomatic anemia [10, 11]. This has been attributed primarily to smaller surgical exposures, minimal bony cuts, and the lack of need to access long bone intramedullary canals [11]. Despite these unique advantages, the incidence of postoperative blood transfusion occurs in up to 0.5% of patients undergoing UKA [12].

Current practice trends suggest a steady increase in the use of blood products in the health care system, increasing up to 6% per year [13]. This has resulted in multiple shortages of blood products and has increased the cost of both acquisition and use. Moreover, multiple studies have now demonstrated the potential adverse effects associated with the overuse of autologous and allogeneic blood transfusions including higher rates of postoperative infection, slower physical recovery, increased length of hospital stay, and increased morbidity and mortality [14]. As a result, the deployment of a patient blood management (PBM) protocol can potentially help mitigate these adverse effects and allow for appropriate use of patient, hospital, and healthcare system resources, thereby allowing for minimization of the consequences of postoperative blood loss anemia while also optimizing the patient's recovery process [13].

PBM has been defined as the "timely application of evidence-based medical and surgical concepts designed to maintain hemoglobin concentration, optimize hemostasis, and minimize blood loss, in an effort to improve patient outcome." [15] In this chapter, we present a concise overview of the preoperative, intraoperative, and postoperative blood preservation strategies available to patients undergoing elective total joint arthroplasty.

Preoperative Strategies

The influence of preoperative hemoglobin on the need for perioperative transfusion has been well established in the arthroplasty literature [16,

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17]. In one study, very few patients with preoperative hemoglobin levels greater than 15.0 g/dL required allogenic blood transfusion, whereas, patients with preoperative hemoglobin levels less than 13.0 g/dL were at 15.3 times greater risk to need a blood transfusion than those with a preoperative hemoglobin levels greater than 15.0 g/dL [17]. Similarly, other patient characteristics, including weight, age greater than 75 years, male gender, hypertension, and body mass index (BMI) less than 27 kg/m^2, have also been associated with increased risk of postoperative transfusion [6, 17]. These risk factors have been proposed to impart a synergistic increase in the risk of transfusion, when more than one risk factor is present [18]. As such, efforts targeted at preoperative optimization of these risk factors are integral in decreasing perioperative transfusion risk. Thus, in patients with multiple risk factors, all modifiable characteristics should be targeted for optimization in the preoperative period.

Subsequently, multiple guidelines have advocated for a detailed medical evaluation at least 3 weeks prior to an elective arthroplasty procedure in order to allow for sufficient time for the effects of any optimization intervention [13, 19, 20]. In general, preoperative optimization strategies have included iron, folate, vitamin B12 supplementation, erythropoietin (EPO), and preoperative autologous blood donation (PAD).

Erythropoietin

EPO is a glycoprotein that is normally produced in the kidneys in response to decreased oxygen tension. The latter typically occurs in various pathophysiological states including anemia or in the setting of pulmonary diseases (i.e., COPD). EPO functions by increasing the rate of red blood cell (RBC) maturation and differentiation in the bone marrow and thus functions to increase overall RBC mass. Commercially, EPO is available in the recombinant form and has been widely used in patients with anemia of chronic disease. In arthroplasty, EPO has been used either alone preoperatively, in conjunction with PAD preoperatively, or postoperatively [21]. Multiple different dosing strategies are available [22], but the use of preoperative EPO has been shown to be most effective in scenarios where large blood losses are expected [16].

Vitamin Supplementation

Multiple vitamins including folate, vitamin B12, and iron are integral to the production of RBCs. Deficiencies in these macronutrients have been associated with various macrocytic and microcytic anemias, respectively. As previously noted, multiple guidelines now suggest formal evaluation for the cause of anemia in patients scheduled to undergo elective arthroplasty. Preoperative supplementation with iron, vitamin C, and folate for 30–45 days before surgery has been associated with lower transfusion rates in at least one series [23]. On the other hand, other studies have demonstrated no benefit of iron supplementation with respect to minimizing postoperative hemoglobin levels [24]. Further, iron supplementation has also been associated with medication side effects including constipation, reflux symptoms, and abdominal pain. Thus, current evidence seems to at least weakly support maximizing supplementation of anemia-associated vitamins. Iron supplementation, on the other hand, is not recommended for routine use.

Preoperative Autologous Donation of Blood (PAD)

PAD is defined as the procurement of a patient's blood prior to surgery. Typically, the patient donates 1–2 units of blood, at least 3 weeks prior to the planned elective procedure to allow for preoperative hemoglobin levels to recover. The patient's autologous blood is then used as a substitute for transfusion of allogenic units either during surgery or postoperatively.

The routine use of PAD in elective arthroplasty surgery has mostly fallen out of favor. Initial studies comparing PAD with preoperative EPO administration demonstrated lower transfusion rates in the PAD group (28% vs. 8%)

[25]. Yet others have reported lower allogenic transfusion rates in patients receiving EPO than those undergoing PAD [20]. PAD decreases preoperative hemoglobin stores and also requires advanced planning, preparation, and storage of the donated units of blood, which could potentiate issues with bacterial contamination, infection, and clerical errors [20, 21, 26–28]. Moreover and somewhat surprisingly, some studies have demonstrated an increased risk of postoperative autologous and/or allogenic transfusions with the use of PAD [28]. Thus, in modern practice, PAD may play a role only in procedures with high expected blood loss, such as bilateral or revision procedures, and its routine use is no longer recommended [29].

Intraoperative Strategies

Intraoperative strategies, like the name implies, refer to approaches to reduce blood loss both during and immediately after surgery. Multiple intraoperative options are available and are discussed further below.

Acute Normovolemic Hemodilution (ANH)

ANH is a similar concept to PAD discussed above. ANH differs, however, in the timeframe in which autologous blood is harvested from the patient. In ANH, blood donation occurs just prior to or at the time of surgery. The donated blood can then be transfused back to the patient postoperatively. The main advantage of ANH over PAD relates to the decreased potential for transfusion clerical errors, bacterial contamination, and wasted units, since blood harvest occurs just before or at the time of surgery [13]. However, the main disadvantages include higher cost and potential for greater blood loss, although the latter has not approached statistical significance [30]. In general, the current literature on ANH is conflicting, partly due to difference in outcome measures and comparators [29–31]. Thus, the role for ANH remains limited in current practice and is often reserved only for select patients including those with religious or personal beliefs against receiving allogeneic blood transfusions.

Tourniquet

Pneumatic tourniquets have long been used in knee arthroplasty due to their potential to offer a “bloodless” surgical field, improved cement interdigitation, and decreased surgical time [32]. Multiple studies have demonstrated shorter surgical times with tourniquet use in TKA [32, 33]. Decreased surgical time, in turn, offers the potential for minimization of hidden blood loss, and by corollary, transfusion rates; however, most studies have failed to demonstrate a significant difference in blood loss, change in hemoglobin levels, or transfusion requirements with tourniquet use [34, 35]. Further, tourniquet use is potentially associated with increases risk of venous thromboembolic events [33], arterial thrombosis [36], and postoperative wound complications [37]. Thus, orthopedic surgeons should balance these risks with the potential benefits of tourniquet use and tailor their decision making to individual patients.

Bipolar Sealants and Argon-Beam Coagulation (ABC)

Bipolar electrocautery sealant devices couple continuous flow of saline with electrocautery. These devices offer the theoretical advantage of being able to minimize thermal damage to soft tissues by maintaining a cool electrocautery tip, while still allowing cauterization of blood vessels. In general, bipolar electrocautery has not shown any significant difference in terms of blood loss, postoperative hemoglobin, transfusion rate, or drain output when compared to traditional monopolar electrocautery, in multiple randomized controlled trials [28, 38, 39].

ABC, on the other hand, works by using ionized argon gas to deliver radiofrequency cauterization. The argon gas theoretically improves visualization and decreases the zone of tissue necrosis, thereby decreasing soft tissue injury. Overall, data are still limited on the use of both of these devices. While they offer theoretical advantages, they are potentially associated with increased costs and lack of clear benefit.

Antifibrinolytic Agents

Antifibrinolytic agents including tranexamic acid (TXA) are competitive inhibitors of plasminogen, thereby preventing its conversion to plasmin and its further conversion to fibrin. These agents work to stabilize fibrin clots and decrease fibrinolysis, thus helping achieve hemostasis. TXA is by far the most widely studied antifibrinolytic agent in total joint arthroplasty and can be administered in intravenous, oral, and topical formulations. The efficacy of TXA in decreasing blood loss and transfusion rates has been demonstrated in multiple randomized controlled trials and meta-analyses [40–44]. Recent clinical practice guidelines endorsed by the American Association of Hip and Knee Surgeons (AAHKS), American Society of Regional Anesthesia and Pain Medicine (ASRA), American Academy of Orthopaedic Surgeons (AAOS), the Hip Society, and the Knee Society have advocated for the administration of TXA (irrespective of formulation or dosage) in patients undergoing primary joint arthroplasty due to its well-established safety and efficacy profile [45].

Topical Hemostatic Agents

Topical hemostatic agents include a wide array of therapeutics including fibrin sealants, platelet-rich plasma (PRP), platelet-poor plasma, collagen agents, and cellulose. Of these agents, fibrin sealants are the most closely studied agents in the orthopedic literature. Fibrin sealants typically have two separate mixtures of coagulation proteins including fibrinogen, factor XIII, thrombin, and calcium. When the two mixtures are combined, a fibrin seal is formed. In one randomized controlled trial, a statistically significant difference in the mean reduction of hemoglobin concentrations was found on the first postoperative day in patients treated with a fibrin sealant when compared to the nontreated controls [46]. While these initial results were encouraging, several other studies have noted no clinically significant differences between postoperative drain outputs, hemoglobin concentrations, transfusion rates, or postoperative complications between treated and control groups [47]. As such, the routine use of these agents must again be considered carefully.

Postoperative Strategies

Transfusion Triggers

Stringent transfusion algorithms have become one of the most effective means to reduce the rate of allogenic blood transfusion. Newer, more restrictive transfusion protocols have decreased the rate of allogenic blood transfusion while imparting no change in cardiovascular morbidity or mortality or length of hospital stay [48]. Thus, the American Association of Blood Banks' clinical practice guideline on transfusion now recommends the restriction of allogenic blood transfusion to patients whose hemoglobin is less than or equal to 8 g/dL and exhibit symptoms of anemia [49]. This recommendation has been supported in the orthopedic literature in several studies [50–52]. Current guidelines now recommend that patients with hemoglobin levels less than 6 g/dL receive red blood cell transfusions and patients with hemoglobin levels greater than 10 g/dL not receive a transfusion, regardless of their physiological reserve [49]. For patients with hemoglobin levels between 6 and 10 g/dL, the decision to transfuse should be based on expectation of continued blood loss, intravascular volume status, cardiovascular reserve, and symptoms of anemia [49].

Reinfusion Drains/Systems

Reinfusion systems rely on the acquisition of shed blood either intraoperatively through red cell salvage suction systems or postoperatively through reinfusion drains. The shed blood, once collected, is then filtered, lavaged, and reinfused back into the patient. Thus, these systems can serve as alternatives to allogenic transfusions. The published literature on their efficacy still remains controversial. In one randomized controlled trial, the use of a postoperative reinfusion systems was found to produce a notable decrease in allogenic transfusion requirement [53], whereas in other studies, use of these devices resulted in no difference in transfusion requirement and came at the expense of significantly higher postoperative blood loss [54]. The latter has been thought to be secondary to the characteristics of the shed blood, which contains increased concentrations of tissue plasminogen activator (tPA) and lower levels of fibrin compared with normal blood. This has been proposed to produce a net effect of fibrinolysis and thus increased postoperative drainage [55, 56].

Conclusion

The deployment of a patient blood management protocol can potentially help minimize perioperative blood loss associated with many arthroplasty procedures. From the discussion presented above, it is clear that there are multiple different blood conservation strategies available to the modern orthopedic surgeon. Some of these strategies are supported by robust clinical evidence, establishing both safety and efficacy for their use. Others offer theoretical and/or plausible benefits, but their clinical efficacy remains equivocal. This discordance highlights the importance of tailoring blood management protocols to the individual patient, based on the preoperative evaluation of the patient's comorbidities, estimated blood loss of the surgical procedure, and potential patient response to anemia. Ultimately, these preoperative, intraoperative, and postoperative blood preservation strategies are all tools in the armamentarium of the orthopedic surgeon to aid in optimizing patient recovery and minimize overutilization of otherwise constrained resources.

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