

INVITED ARTICLE

Blood Conservation in Scoliosis Surgery

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ABSTRACT

Spinal deformity correction surgery can result in significant blood loss. Historically, large volumes of allogeneic blood transfusion were used in these patients. There is now an increasing awareness of the need to reduce allogeneic transfusion as there are reported adverse effects. Reducing blood loss during scoliosis surgery is a multipronged approach. This study reviews current strategies to reduce requirements for allogeneic blood transfusion for scoliosis corrective surgery.

Keywords: Blood loss, Blood salvage, Blood transfusion, Scoliosis, Spine surgery.

How to cite this article: Verma R. Blood Conservation in Scoliosis Surgery. *J Postgrad Med Edu Res* 2017;51(2):68-73.

Source of support: Nil

Conflict of interest: None

INTRODUCTION

Spinal deformity correction surgery can be associated with high levels of blood loss, necessitating increasing levels of blood transfusion. Blood loss can be related to patient factors, sex, Risser sign, preoperative Cobb angle, preoperative kyphosis magnitude, activated partial thromboplastin time level and fibrinogen level, and menstruation cycle phase or procedure-related variables.¹⁻⁵

Multisegmental surgery, bony osteotomy, length of surgery, and complex revision surgery can result in massive blood loss.^{6,7}

Surgery for spinal deformity is associated with high levels of blood loss that may be increased with certain patient factors and complex or revision procedures that include osteotomies.^{1,8,9}

The main risks/complications of blood transfusion fall into either infectious or noninfectious categories. Allogeneic transfusions are associated with an increased risk of surgical site and systemic infection, transmission of infectious agents, acute hemolytic reactions, and transfusion-related immune modulation.¹⁰⁻¹³ Moreover, both autologous and allogeneic transfusions contribute

to longer hospital stay and, consequently, increased hospital costs.^{14,15}

Massive transfusions also put patients at risk of metabolic abnormalities, dilution of clotting factors, and hypothermia.^{16,17} Any intervention that can minimize the requirement for transfusion would have a significant beneficial effect on this patient cohort.

Exactly when is a blood transfusion necessary? The “absolute” threshold for red blood cell (RBC) transfusion is a controversial moving target, especially in the pediatric population, and the trend has been toward a lower absolute hemoglobin (Hb) transfusion trigger over the years. In the adult population, for many years, anesthetists and intensivists often transfused to keep the Hb at or above 10 to 13 g/dL, based mainly on clinical experience.

More recently, the American Society of Anesthesiologists has recommended transfusing if the Hb is less than 6 g/dL, although they do not advocate a single transfusion trigger but rather assessment of the patient’s comorbid conditions and current state. The American Association of Blood Banks advises using an Hb threshold of 7 to 8 g/dL in stable hospitalized patients. Most recommendations for the pediatric population are based either on expert opinion or derived from adult studies, but as in the adult population, the trend has been toward tolerating lower Hb concentrations.^{18,19}

PREOPERATIVE

Before surgery, routine preoperative laboratory tests, including prothrombin time (PT), partial thromboplastin time, international normalized ratio, and complete blood count, should be performed. Careful investigation of patient bleeding history or history of easy bruising is recommended. Hemoglobin and hematocrit levels should be reviewed before surgery. In patients where a low hemoglobin is identified before surgery, commencement of ferrous sulfate may help to improve levels before surgery. In orthopedic procedures overall, a hemoglobin level of less than 13 g/dL has been associated with higher transfusion risk in orthopedic procedures.²⁰

Patients with anemia were found to be more likely to have longer hospital stays, experience one or more complications, and suffer mortality within 30 days of surgery.²¹ Recent study has recommended setting a minimum preoperative Hb value that is 5 g/dL higher than the transfusion trigger. Of 86 patients who underwent posterior instrumented fusion for adolescent

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idiopathic scoliosis (AIS), none required intraoperative allogeneic transfusion. Only 4 patients (4.65%) received allogeneic transfusion, all within 2 days of surgery.¹⁹

PREOPERATIVE AUTOLOGOUS BLOOD DONATION

Preoperative autologous blood donation uses preoperative donations made by the patient in advance of surgery.²²

The goal behind the use of autologous blood is to prepare blood for intraoperative or postoperative transfusion without the potential risk for blood-borne pathogens, blood type mismatch, or immunological adverse effects associated with allogeneic blood exposure.

The limitations to autologous blood donation before major spine surgery include the potential for preoperative anemia and an inability to obtain sufficient units of blood.²³ In addition, autologous blood donation is not cost-effective if more than 15% of the donated blood must be discarded.²⁴

The optimal strategy for timing preoperative donation, as well as the number and type of units is a matter of debate. Whole blood has the advantage of being the most physiologic. However, coagulation factors experience substantial degradation as early as 8 hours after donation.

If the donated blood is separated into red cells and fresh frozen plasma, the storage life becomes much longer. This does, however, require special processing and added cost.

ERYTHROPOIETIN

Erythropoietin is a hormone produced predominantly by the peritubular cells of the kidney that promotes maturation of proerythrocytes to reticulocytes and differentiation of circulating reticulocytes to mature RBCs.

The rationale behind preoperative administration of erythropoietin before surgery is to optimize preoperative hemoglobin and hematocrit levels to facilitate preoperative autologous blood donation or to enhance hematocrit at the start of surgery.

In a randomized, controlled trial, Shapiro et al²⁵ showed that patients who received erythropoietin before preoperative autologous donation programs were more likely to be able to complete them, less likely to require allogeneic transfusion, and had shorter hospital stays compared with patients who did not receive erythropoietin.

The presumption behind its use is that increasing baseline hematocrit is likely to decrease the transfusion needs during and after surgery.

Patients who had preoperative hemoglobin values of 10 to 13 g/dL who received erythropoietin 10 days

before surgery until 4 days after surgery were less likely to require allogeneic blood than patients who had not received erythropoietin.²⁶ Other authors have reported similar findings.²⁷

Studies evaluating erythropoietin have acknowledged the theoretical risk of thromboembolic events, although none have found a statistical increase in rates of clinically significant events.^{20,26,27}

A recent study examining the adverse effects related to erythropoietin use in spine surgery by Stowell et al²⁸ found an increased rate of deep vein thrombosis in patients who had erythropoietin but no difference in other thromboembolic events. An additional hurdle is the associated cost of routine administration of intramuscular injections of erythropoietin.

ANESTHETIC CONSIDERATIONS

Gardner²⁹ first reported the use of intraoperative hypotension in 1946. In 1974, McNeill et al³⁰ reported a 40% decrease of intraoperative blood loss with the use of induced hypotension in scoliosis surgery.

Controlled hypotension can be used intraoperatively to limit blood loss. Decreasing mean arterial pressure leads to diminished blood flow to the surgical field, resulting in less blood loss over the course of surgery.³¹

Authors have reported similar findings using only moderate hypotension with mean arterial pressures of 80 mm Hg.^{32,33} Since then, mean arterial pressures as low as 60 mm Hg have been reported without adverse sequelae. The use of induced hypotension has also been shown to independently decrease the need for blood transfusions by approximately 45% and to decrease operating time by 10%.³⁴

While complications from hypotensive anesthesia have been described, they remain exceedingly rare in young, healthy patients who undergo major spinal surgery.^{30,32-40} However, there has been some concern over end-organ hypoperfusion that has been reported with this technique, including cardiac ischemia, renal failure, and blindness.⁴¹

Visual loss, particularly ischemic optic neuropathy, is one of the most concerning complications that may be associated with hypotension.³⁸ Intraoperative hypotension must be used judiciously and may be an easy culprit for ischemic optic neuropathy in a lawsuit. However, to date, there remains no proven causation effect. This complication is exceedingly rare and is multifactorial in nature.

It is important to keep the patient warm and monitor the core temperature throughout the surgical procedure. Even early hypothermia can prolong PT and result in increasing blood loss.

INTRAOPERATIVE CELL SALVAGE

Perioperative autologous cell salvage (i.e., cell saver) is an intraoperative autologous blood transfusion technique in which blood lost during surgery is collected, anticoagulated, and centrifuged to separate RBC from plasma contents and subsequently infused back to the patient.

In a retrospective case–control study by Bowen et al,⁴² pediatric patients undergoing posterior spinal fusion for idiopathic scoliosis were separated into two groups based on cell saver use. Intraoperative cell saver use was associated with decreased allogeneic transfusion in surgeries lasting over 6 hours and in cases of large intraoperative blood loss (>30% of total blood volume).

Currently, many authorities find intraoperative blood salvage to be an effective blood management technique, despite the relatively expensive device and technical expertise required to operate it.⁴³

ANTIFIBRINOLYTICS

In normal hemostasis, platelet adhesion and activation spurs initiation of the coagulation cascade. The end result of this cascade is a fibrin clot. Subsequently, plasmin-mediated fibrinolysis occurs, causing dissolution of the fibrin clot. Antifibrinolytic agents, such as epsilon-aminocaproic acid (EACA), tranexamic acid (TXA), and aprotinin interfere with plasmin-mediated fibrinolysis without serving any prothrombotic function.⁹

The TXA and EACA have been associated with decreased blood loss in spine surgery.⁴⁴

The accepted dosing for TXA is 10 mg/kg as a loading dose, with 1 mg/kg/hour for maintenance until incision closure, while the dosing for EACA is 100 mg/kg as loading dose, with 10 mg/kg/hour for maintenance until incision closure.⁴⁵ In the pediatric surgical literature, TXA doses as high as 100 mg/kg as a loading dose with 10 mg/kg/hour maintenance have been explored.⁴⁶ The ideal dose and duration of TXA for pediatric and adult scoliosis patients remains debated and is a direction for future study.

In a small, prospective, randomized, double-blinded study, Elwatidy et al⁴⁷ showed that large prophylactic doses of TXA during spine surgery could reduce the blood loss by 49% and decrease transfusion needs by 80%.

ACUTE NORMOVOLLEMIC HEMODILUTION

Acute normovolemic hemodilution is thought to decrease allogeneic transfusion needs in patients with spine deformity. It works under the rationale that lowering the hematocrit, while maintaining volume status, reduces RBC losses during surgery. Although blood volume loss should not change, fewer RBCs for the same volume of blood are lost because of decreased RBC concentration in the blood.

In acute normovolemic hemodilution, the first step is to carefully remove whole blood from the patient, while simultaneously maintaining the patient's volume status by infusing crystalloid solution. The autologous blood is collected and saved. The patient then undergoes spine surgery in a hemodiluted state, minimizing RBC loss throughout the procedure. After or during the operation, the autologous blood collected at the beginning of the procedure is transfused back into the patient.

As an additional benefit, normovolemic hemodilution may induce a mild hypercoagulable state.^{31,48,49} This may help to control intraoperative blood losses as well.

The adverse effects of normovolemic hemodilution are not well reported in the literature. Theoretically, a major caveat to normovolemic hemodilution is to avoid lowering the hematocrit to compromise oxygen delivery to the tissues.⁵⁰

Overall, normovolemic hemodilution has been shown to be moderately effective at reducing exposure to allogeneic blood products, with less than one-third of studies reporting any adverse events related to this method.^{51,52}

SURGICAL STRATEGIES

One mainstay of orthopedic surgical practice is proper patient positioning. Relton and Hall⁵³ reported a significant decrease in intraoperative inferior vena cava pressure secondary to use of the Relton–Hall frame. By leaving the abdomen free in the prone position, there is decreased inferior vena cava pressure and thus decreased venous plexus filling around the spinal cord. Theoretically, there is also decreased vertebral venous pressure and, consequently, reduced intraoperative blood loss from decreased bone bleeding.

Other strategies aimed at reducing intraoperative blood loss include electrocautery, meticulous wound packing, and hypotensive anesthesia.

The use of a bipolar sealer device during posterior spine fusion in AIS significantly lowers total perioperative blood loss and reduced the transfusion rate in half when compared with using conventional monopolar electrocautery alone.⁵⁴

This device uses radiofrequency energy in combination with saline irrigation to cause coagulation and sealing of soft tissue and bone at a much lower temperature (<100°C) than standard electrocautery.^{55,56}

A dual attending surgeon strategy was shown to be superior to a single surgeon strategy in posterior selective thoracic fusion in Lenke 1 and 2 AIS patients and leads to a quicker operation, reduced intraoperative blood loss, reduced risk of allogeneic transfusion, reduced morphine requirement, and shorter hospital stay.⁵⁷

INTRAOPERATIVE HEMOSTASIS

Intraoperative hemostasis plays an important role in controlling blood loss. A number of tools exist for surgeons, including topical thrombotic agents and bipolar sealers. Local topical thrombotic agents are numerous in number and are an area of constant development.

Typically, topical thrombotic agents combine a matrix for mechanical compression and hemostasis, such as collagen, gelatin, and foam-based materials. They are often combined with chemical hemostatics, such as thrombin.⁵⁸

The use of these types of combination hemostatic agents has become helpful during surgery (e.g., FloSeal, Baxter International, Deerfield, Illinois).

Topical hemostatic agents are not without adverse effects. Plasma-derived bovine thrombin, for example, may lead to the development of autoantibodies and subsequent bleeding and thrombotic complications in the postoperative period.

Expansion of hemostatic agents can cause compression of neural elements when placed in the spinal canal. Foreign body reactions can occur with mechanical hemostatic agents that fail to reabsorb.³¹

Bone bleeding is often encountered in orthopedic surgery and can often be difficult to control. Bone wax is a nonabsorbable mixture of beeswax (70%) and petroleum jelly (30%) and can be used to control bleeding from the bone.⁵⁹ Bone wax utilizes its physical properties to stop bleeding. However, bone wax also has been shown to inhibit osteogenesis, so its use should be judicious and avoided in the fusion bed if possible.⁵⁹

CONCLUSION

Blood is a scarce human resource, and there is a persuasive economic argument against the overuse of blood, analogous to the overprescription of drugs. Responsibility for ordering blood or blood components and the decision to transfuse rest ultimately with the attending clinician.

The risks of blood transfusion in India are significant. Multiple transfusion recipients have high rates of human immunodeficiency virus, hepatitis B, and hepatitis C infection,⁶⁰⁻⁶² and several prospective studies enumerate the risk of developing posttransfusion hepatitis.^{63,64} Saxena et al⁶⁵ followed up 182 transfusion recipients, at a Delhi hospital, who received an average of 4 to 5 units of blood; 7.7% developed posttransfusion hepatitis. National Blood Policy in India aims to ensure easy accessibility and adequate supply of safe blood and blood components, available according to need.⁶⁶ The annual approximate requirement of blood in India is estimated to be 12 million units. However, a World Health Organization report estimated a 3 million unit shortage.⁶⁷

Utilizing all the various blood conserving strategies in patients undergoing surgery for spinal deformity correction will lower the requirement for allogeneic blood transfusion and help preserve blood stocks, thus avoiding potential complications of blood transfusion in this patient group.

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