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REVIEW

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An overview of blood-sparing techniques used in spine surgery during the perioperative period

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Abstract The problems linked to blood loss and blood-sparing techniques in spine surgery have been less studied than in other fields of orthopedics, such as joint-replacement procedures. Decreasing bleeding is not only important for keeping the patient's hemodynamic equilibrium but also for allowing a better view of the surgical field. In spine surgery the latter aspect is especially important because of the vicinity of major and highly fragile neurologic structures. The techniques and agents used for hemostasis and blood sparing in spinal procedures are mostly similar to those used elsewhere in surgery. Their use is modulated by the specific aspects of spinal approach and its relation to the contents of the spinal canal. Blood-sparing techniques can be divided into two categories based on their goals: either they are aimed at decreasing the bleeding itself, or they are aimed at decreasing the need for homologous transfusion. Various hemodynamic techniques, as well as systemic and local drugs and agents, can be used separately or in combination, and their use in the field of spine surgery is reported. The level of evidence for the efficacy of many of those methods in surgery as a whole is limited, and there is a lack of evidence for most of them in spine surgery. However, several blood-saving procedures and drugs, as well as promising new agents, appear to be efficient, although their efficacy has yet to be assessed by proper randomized controlled trials.

Keywords Hemostasis · Spine surgery · Bleeding · Blood sparing · Prevention

Introduction

Blood loss in spine surgery is an important issue, even though it appears underestimated, or at least understudied, compared to hip and knee arthroplasty surgery. Blood loss, however, may be an acute problem not only in major deformity surgery but also in less extensive fusion procedures. Decreasing bleeding is important for maintaining a patient's hemodynamic equilibrium and allowing a better view of the surgical field. In spine surgery, the latter aspect is especially important because of the vicinity of major and highly fragile neurologic structures. The surgeon's comfort shortens surgery time, which further decreases bleeding.

In this article we will summarize the main techniques used to spare blood in spine surgery during the perioperative period: from the immediate pre-op to the post-op period. Most of those modalities will be described in greater detail elsewhere in this issue.

Blood-sparing techniques

Blood-sparing techniques can be divided into two groups based on their goals: they are aimed either at decreasing the bleeding itself, or at decreasing the need for homologous transfusion.

Methods aimed at decreasing bleeding

Hemodynamic:

- Controlled hypotension
- Local vasoconstrictors
- Epidural blockade

Chemical/biological:

- Systemic:
  - Desmopressin
  - Aprotinin
  - Tranexamic acid
  - Epsilon-aminocaproic acid
  - Oestrogens
  - Other
- Local:
  - Bone wax
  - Hemostatic "sponges" (gelatin, collagen, cellulose)
  - Fibrin sealants
  - Other

Methods aimed at decreasing homologous transfusion needs

Hemodynamic:

- Acute hemodilution
- Planned autologous transfusion
- Blood saving:
  - Perioperative: cell saving systems
  - Postoperative: drainage recovery systems or cell saving

Chemical/biologic:

- Erythropoietin (EPO)
- Substitutive oxygen carriers

Planned preoperative autologous donation and erythropoietin treatment will not be discussed here, as they take place many weeks prior to surgery and, therefore, are not truly perioperative. This paper will discuss all blood-sparing techniques reported in orthopedics, even if they have not (yet) been published in the context of spine surgery.

Controlled hypotensive anesthesia

Controlled hypotension has been used with success since the 1950s in orthopedic surgery [52]. It is widely applied to spine surgery, and good results have been published since the early 1970s [44, 66, 72, 84, 87, 91, 109].

However, Lennon et al. [77] report in a retrospective study that hypotensive anesthesia did not decrease transfusion requirements compared with normotensive narcosis in scoliosis surgery. The goal of hypotensive anesthesia is to reach a systolic blood pressure of around 60–80 mm Hg. Many different drugs have been used over time, such as anesthetic gases [13], Ca channel blockers [75], beta-blockers [80], nitroglycerin, nitroprusside [59, 50], opiates [21] and anesthetic drugs.

The mechanism by which controlled hypotension decreases blood loss is still unclear and goes beyond the simple explanation that lower blood pressure induces lower blood extravasation. Some authors have hypothesized the existence of an ischemic wound during hypotensive anesthesia, but few studies have really tried to measure blood flow through scientific measures such as flowmetry. Lee et al. measured blood flow in the paraspinal muscles during spine surgery with two different hypotensive drugs, reaching a similar degree of hypotension. They found widely different values for local blood flow [73], although the blood losses were not very different. This indicates that the effect on local blood flow is not the only factor involved. The effect on blood flow in the epidural venous plexuses has also been hypothesized [74], and blood pressure by itself seems to be an important variable influencing blood loss [100].

In the context of spinal fusions, some authors report that, since bleeding is mainly linked to bone decortication and is, therefore, essentially venous, blood loss will not be influenced by a decrease in arterial pressure [15]. In their series of Jehovah's Witnesses, Brodsky et al. [15] found that blood flow was correlated to surgery duration more than to blood pressure. Kakiushi [62] measured intraosseous pressure in thoracic vertebral bodies during surgery and found that the intraoperative blood loss correlated with intraosseous pressure but that the latter was not correlated to the arterial pressure.

Hypotensive anesthesia may lead to complications [81] and is contraindicated in some cases, mainly in patients with hypertension or ischemic disorders: coronary, cerebral or peripheric.

The possibility of neurological damage at the level of already compressed and compromised nerve roots, where hypotension could add to the suffering of the root, was raised by Krengel et al. [69]. The effect of hypotension on spinal cord function during scoliosis surgery has also been questioned [44]. However, although evoked potential monitoring may show temporary alterations, it does not appear that hypotensive anesthesia increases the risk of neurologic damage [45].

Acute normovolemic hemodilution

In this technique venous blood is collected at the beginning of the procedure, after the induction of anesthesia, in order to diminish hematocrit to a level around 30. In children even lower values can safely be attained (under 20) [33, 101]. The lost volume is compensated with synthetic colloids. Hemodilution can be combined with hypotensive anesthesia.

Despite the hemoglobin loss, tissue oxygenation is maintained through increased cardiac output and better venous return due to reduced viscosity, shear and sludge effect. Furthermore, the loss of red blood cells is decreased, as the blood volume lost during surgery will contain fewer cells. The collected blood can then be retransfused according to need.

Acute normovolemic hemodilution is widely used in spine surgery with good results in fusion [55, 60, 88], as well as in scoliosis surgery [11, 24, 30]. The patient can be kept in hemodilution beyond the surgical-procedure duration by delaying transfusion until the next day, with transfusion then being performed based on clinical judgment [55]. The main contraindications to this technique are ischemic disorders and hemoglobinopathies.

Local vasoconstrictors

Local infiltration of paraspinal muscles with vasoconstrictors (epinephrine, ornipressin) is widely used in spine surgery. This is based on the common belief that vasoconstriction will decrease blood loss. However, the literature is very scarce, and there is little evidence of true efficacy [11]. Also, blood loss does not appear to be related to the dose injected [47].

Epidural blockade

Epidural blockade with normotensive anesthesia has been described as reducing blood loss [61]. It induces vasodilatation in the pelvis and lower limbs with a reactive vasoconstriction above the blocked level and, therefore, can only be used at the lumbar level.

Postoperative wound instillation

Bianconi et al. [12] reported that postoperative wound instillation with ropivacaine was effective in controlling pain and decreasing postoperative blood loss.

Lost blood salvage

Perioperative

With this technique, blood lost during surgery is recuperated and processed through a pump system (Cell Saver, Haemonetics), then transfused back to the patient. In this case it is scavenged blood that returns to the patient. It does not contain platelets or coagulation factors. Therefore, in the case of significant loss and return, a supplementation with fresh-frozen plasma is required [70]. This means that the need for homologous blood products is not entirely eliminated in this method. It is estimated that about half of the lost red blood cells can be salvaged [37].

The main complication is that a dilutional or disseminated coagulopathy can occur, and there is also a question about the complete elimination of tissue residues. Cell saving is therefore contraindicated in the presence of coagulopathies. Other rare complications include pulmonary injuries probably linked to leukoagglutinins [113] and transient hemoglobinuria [37]. This technique has been reported to be effective in spine surgery [10, 77, 84]. However, Copley et al. [24] did not show an efficacy in cell saving in conjunction with hypotensive anesthesia or with hemodilution in adolescents undergoing surgery for idiopathic scoliosis, and concludes that, in these cases, the cost exceeds the benefit. Shulman et al. compared acute normovolemic hemodilution and hemapheresis for blood-component sequestration with salvage alone. They found that the first technique was more cost effective, decreasing allogeneic as well as autologous blood need [99]. In a meta-analysis, Huet et al. [53] conclude that cell salvage in orthopedic surgery decreases the frequency of allogeneic transfusions, and a recent Cochrane review on cell salvage in surgery suggests that it is efficient in reducing need for allogeneic transfusion, despite the poor methodological quality of most studies [18, 19].

Postoperative

Postoperative collection and transfusion of either washed (cell saving) or unwashed blood has been described in many surgical fields. The most frequent technique consists of re-infusing filtered but unwashed blood from the wound-drainage systems. Many questions remain about the safety and real efficacy of this technique; e.g., the viability of the recovered erythrocytes is doubtful. The nephrotoxicity of free hemoglobin, originating from the hemolyzed red blood cells, poses a safety concern. Furthermore, the efficacy of the filtering system on all tissue residues and metabolites is not entirely clear. However, it seems that, although serum levels of fibrin-degradation products, free hemoglobin and some enzymes [97] increase, they return to previous levels after 24 h. Minor transient transfusion reactions may occur: chills, tachycardia and temperature-increase [103]. Infection and malignancy are contraindications.

This technique is very widely used in hip and knee arthroplasties. There are a few publications in the field of the spine, and these claim efficacy in reducing homologous transfusion requirements [10, 84]. Sebastian et al. [97] showed a reduction of 30% in transfusion needs after reinfusion of drainage-salvaged blood. A combination of intraoperative cell saving with the postoperative infusion of unwashed shed blood enabled Behrman to decrease transfusion requirements by 68% in spinal procedures [10].

Systemic drugs

Epsilon-aminocaproic acid (EACA):
Hemocaprol, Amicar (Lederle) and others

This is an antifibrinolytic agent that prevents plasmin from binding to fibrin. Some rare complications have been described: deep venous thrombosis, pulmonary embolism, renal failure and severe bradycardia.

In the field of spine surgery there are scarce and conflicting results published. In a controlled but not blinded study [35] and then in a proper randomized controlled study against placebo [36], Florentino-Pineda et al. showed a decrease in blood loss and transfusion requirements in patients undergoing idiopathic scoliosis surgery. In fusions in adults, Urban et al. showed limited effect, EACA being only marginally more effective than placebo but much less effective than aprotinin [110]. Amar et al. [5] used it in major orthopedic surgery (including spine) in patients with malignancy and found no efficacy. In a Cochrane review on antifibrinolytic drugs in surgery, Henry et al. [48] found a trend in favor of the use of EACA, but this was marred by poor methodology and biases in the reviewed articles. In other reviews Kovesi et al. [68] did not find any data to support routine use of EACA in orthopedic surgery, and Erstadt [32] came to the same conclusions concerning all types of surgery (including orthopedics).

Aprotinin: Trasylol (Bayer)

The complete mechanism of action of this substance remains unclear. It appears to decrease fibrinolysis by inhibiting plasmin, trypsin and kallikrein. It also avoids pathologic platelet activation by stabilizing the platelet membrane. Finally, it seems to decrease the inflammatory response by inhibiting bradykinin, interleukin and TNF.

Numerous problems are linked to its use: hypercoagulation, thrombus formation and effect on renal function. There also is a high risk of anaphylactic reaction after previous administration. This is especially important, as this drug is very widely used in cardiac surgery. This risk could preclude the drug's use in heart surgery in those patients having previously received it for other procedures such as spine surgery. In a multicenter randomized controlled trial, Samama et al. [94] have demonstrated a decrease of blood loss and transfusion with aprotinin in major orthopedic surgery. A Cochrane review [48] of antifibrinolytic drugs in surgery found existing evidence for the use of aprotinin, despite biases in some of the reviewed studies.

The use of aprotinin in spine surgery has been documented in a few controlled studies. Urban showed a decrease in blood loss and transfusion needs in adult fusion, and Cole et al. [23] showed similar results in deformity surgery on children and adolescents. Lentschener et al. [78] demonstrated dramatic reduction of intraoperative and 24-h blood loss but did not notice a significant reduction in homologous transfusion needs. This study demonstrated the decrease on intraoperative fibrinolysis through intraoperative dosage of D-dimmer. Amar et al. used aprotinin for major orthopedic surgery (including spine) in patients with malignancy and found no efficacy [5] in reducing blood loss. There are conflicting results as to the dose regimen to be used, with some reporting high dosage [78, 94] and others half-dosage efficacy [110].

Deamino-8-d-arginine-vasopressin
(DDVAP or desmopressin): Minirin (Ferring)

This is an analog to L-arginine-vasopressin or antidiuretic hormone (ADH). Its mechanism of action lies principally in an increase of the secretion of factor VIIIc. It also increases the secretion of von Willebrand factor (vWF) and has a paradoxical effect on the increase of plasminogen activator. There are conflicting reports about the use of desmopressin in scoliosis surgery. In a controlled trial, Kobrinsky et al. [67] found decrease in blood loss, transfusion requirements and use of analgesic agents in the postoperative period. The latter might be due to the decrease of bleeding in the wound. Other studies, however, do not confirm such findings. Alanay et al. [2] conducted a randomized trial against placebo and did not find any significant effect on blood loss in idiopathic or congenital scoliosis. Guay et al. [46] reached the same conclusion.

In neuromuscular scoliosis, where coagulation abnormalities are often present [63, 89], leading to severe blood loss [31], Theroux et al. [104], in a randomized controlled trial, showed that although administration of DDVAP significantly increased factor VIIIc and vWF, it didn't decrease blood loss compared to placebo. Similarly, Lett's et al. [79] conclude that DDVAP decreases bleeding in some patients while others show no response. They propose testing bleeding time after a test dose of DDAVP a few days before surgery.

Several reviews do not find arguments for a wide use of DDAVP in order to reduce surgical bleeding. Kovesi [68] concluded that it can be efficient in patients with a defect in platelet function but found no evidence for use in routine elective orthopedic surgery. A recent Cochrane review of DDAVP in surgery does not find any evidence for surgical use outside patients with congenital bleeding disorders [18]. Desmopressin might be well indicated in patients with von Willebrand disease, acquired platelet disorders, renal failure, cirrhosis or long-term salicylate treatment.

Oestrogens: estriol, conjugated oestrogens

Oestrogens have been widely used in the past for hemostasis. However, their apparent lack of efficacy has made their use scarce [32]. The mode of action is unclear. It seems that they decrease the permeability and increase the resistance of capillary walls as well as improve the platelet/wall interaction. They also have an antifibrinolytic activity by altering levels of factor V and decreasing the antithrombin activity of plasma.

In a controlled study McCall et al. [86] have reported the efficacy of conjugated oestrogens (Premarin, Wyeth-Ayerst) in decreasing the postoperative drainage volume in adolescents having undergone deformity surgery. There were no side effects. In a review of systemic hemostatic drugs, Erstadt [32] found only limited efficacy of conjugated oestrogens in the reduction of blood loss in surgery.

Tranexamic acid: Exacyl (Sanofi-Synthelabo), Cyklokapron (Pfizer) and others

Tranexamic acid decreases fibrinolysis by inhibiting transformation of plasminogen into plasmin. Recent studies show efficacy in reduction of bleeding during hip- [76] and knee-replacement [56] procedures. Other studies, however, seem to show that tranexamic acid does not decrease hidden losses [40]. Meta-analysis of the use of tranexamic acid in surgery shows either specific efficacy in knee arthroplasty [32, 51] or a trend towards effectiveness in other procedures, but results are marred by methodological flaws in the existing publications [48]. In the field of spine surgery, only one double-blind, placebo-controlled study in children and adolescents undergoing scoliosis surgery showed a reduction in transfusion needs without added complications [90].

Recombinant factor VIIa/RhFVIIa (NovoSeven, Novo Nordisk)

This drug is an anti-hemophilic agent. Its efficacy on hemostasis in non-hemophilic subjects during surgery [4], neurosurgery [64] and trauma [43] has been reported. A double-blind randomized control trial has shown good results in prostatic surgery [39]. In spine surgery there are some anecdotal reports [106] but there is currently a lack of evidence, due to a paucity of available studies [68]. This agent seems promising but true evidence of its efficacy in reducing bleeding during spine surgery has yet to be collected.

Other systemic means

Amino-acid infusion that induces thermogenesis prevented a drop in body temperature and decreased blood loss in hip arthroplasty [114]. Likewise, aggressive warming to keep body temperature at 36.5°C appears to decrease blood loss in hip replacement [115]. There are no reports on the effect of warming during spine surgery. Etamsylate (Dycinone, Sanofi-Synthelabo), a drug marketed as hemostatic, was used without success in hip replacement [65], and no data on its use in spine surgery is available.

Substitutive hemoglobin carriers (hemoglobin raffimers)

Substitutive oxygen carriers are an elegant solution for the future [6]. They are often incorrectly called “artificial hemoglobins,” whereas the products in clinical experimentation are made from human or animal stabilized acellular hemoglobin. Hemopure (Biopure) is already marketed in South Africa, although the ethical issues regarding the early commercial human use of such products are discussed [99]. It is a bovine stabilized hemoglobin for which an FDA regulatory filing phase III trial has been completed in orthopedic surgery (including spine). This study showed an important decrease in transfusion needs. There do not appear to be major safety issues [102].

Hemolink (Hemosol) is a similar product but based on human hemoglobin. Results of phase II trials in cardiac surgery have been published showing decreased allogeneic transfusion needs with good safety [20]. A clinical phase III study, along the same lines, shows a marked reduction in the need for transfusions [42]. Phase II trials in orthopedic surgery are on the way in Canada and the US.

Local agents

Bone wax

Bone wax is a mixture of beeswax (70%) and petroleum jelly (30%). It acts in a purely mechanical way, by covering and filling bleeding bone surfaces. Its best known use is probably the hemostasis of sternotomy surfaces. There have been few reports in the field of spine surgery. Abumi et al. [1] describe an injury of the vertebral artery during cervical pedicular-screw insertion that was subsequently stopped with bone wax. Use of bone wax to stop bleeding of the bony surface in the spine is hampered by the fear of leaving a foreign body that can intrude into the spinal canal. Indeed, Cirak and Unal describe a case of tetraplegia following use of bone wax [22].

Hemostatic “sponges”

Gelatin-based (Gelfoam (Pharmacia), Surgifoam (Johnson & Johnson), and others

Gelatin-based, local hemostatic agents have been used in surgery for decades. They can be of bovine, porcine or equine origin and are available in multiple presentations:

sheets, powder, foam, etc. They can be used alone or soaked with thrombin. Their mechanism of action is still not completely clear but appear to be more physical, by "surface effect", than through any action on the blood-clotting mechanism. Gelatin-based devices have been reported to induce a better quality clot than collagen-based products [28]. The substance has been widely used in spine surgery, as it is considered safe to leave in the canal because it does not swell. Some authors have even suggested that gelatin reduces scar adhesion [71].

However, several publications report severe neurological consequences including cauda equina syndromes linked to the use of gelatin products in the spinal canal [3, 9, 38, 49]. Allergic reaction to gelatin after spinal use has also been reported [92].

Collagen-based: Instat (Johnson & Johnson), Lyostypt (B-Braun), Hemocol (Pilling-Weck), and others

Collagen based hemostatic products are from bovine, porcine or equine origin, and also exist in different forms: sheets, powder, aggregates, etc. They act on platelet aggregation and activate Hageman factor (F XII). They should not be left in the spinal canal as they provoke adhesion formation and foreign body reactions.

A more elaborate product is Tachocomb (Nycomed). It consists of a patch of collagen coated with fibrinogen and thrombin. In contact with liquids the components dissolve and the last phase of coagulation is launched, resulting in a fibrin-clot formation. That mode of action is similar to that of the fibrin sealants reviewed later. It also contains aprotinin in order to inhibit clot fibrinolysis. It is mostly used in thoracic and abdominal surgery, but repair of lacerations to the dural sac with this product have been reported [58] and experimental models have shown effectiveness in avoiding epidural fibrosis [73]. The use in spine surgery appears to raise the potential danger of leaving collagen-based agents in the spinal canal.

Oxidized cellulose based: Surgicel (Johnson & Johnson), Curacel (Curaspon) and others

These products also exist in multiple forms, such as sheets, gauze and powder. Their action is essentially a surface effect, which activates the initial coagulation phase. They also induce a moderate acceleration of fibrinogen polymerization. They should not be left in the canal, as they swell and cause foreign-body reactions. Neurological complications have been widely reported [8, 14, 57, 82]. Epidural migration, causing severe, and sometimes permanent, neurological lesions after use of cellulose hemostatic agents for thoracotomy have also been reported [98, 112]. The foreign-body reactions provoked by cellulose may induce granulomas and pseudo tumors [16, 95]. These reactions may also result in misleading pseudo-compression images on MRI examinations [7].

Fibrin sealants

Fibrin sealants reproduce the last phase of coagulation: the formation of a fibrin clot. There are two main families of fibrin sealant. The first combines two components: a fibrinogen component and a thrombin solution. A more recent type of sealant uses the fibrinogen of the bleeding source itself.

Bi-component fibrin sealant: Tissucol/Tisseel (Baxter), Beriplast (Behring), Hemaseel (Haemacure), CoStasis (Cohesion Tech)

All the available sealants in this category are used by mixing a fibrinogen component with a thrombin solution to form a fibrin clot. They usually contain factor XII to speed the cross linking of the clot. Some may contain aprotinin to inhibit fibrinolysis and even plasminogen to control the reaction. They are applied with a syringe, but a sprayable form exists to cover larger surfaces. However, they adhere poorly on wet and bleeding surfaces. Content of the sealant solution is especially important in spine surgery because of possible contact with major neurological structures. Quixil (Omrix, Brussels, Belgium) contains tranexamic acid instead of aprotinin as antifibrinolytic adjuvant. It appears that tranexamic acid is neurotoxic. Fatal neurotoxic reactions have been reported after use in neurosurgery [85].

Fibrin sealants have been reported to be effective in spine surgery [107] and to diminish scar formation [111]. A Cochrane review on the use of fibrin sealants in surgery suggests efficacy, but this conclusion is hampered by the small number of trials and their mostly dubious methodology [17].

The use of bovine fibrinogen may pose a safety problem in the context of spongiform encephalitis and the marketing of one fibrin glue, Biocol, had to be stopped. CoStasis uses the patient's centrifuged plasma with bovine thrombin. It is useful for avoiding the need for bovine fibrinogen (although bovine thrombin remains), but it seems expensive, cumbersome and time consuming. It has been reported to be effective in spine surgery [29, 105].

Fibrin sealant using wound fibrinogen: FloSeal (Baxter, formerly Proceed, by Centerpulse)

This second family of sealants contains thrombin but relies on the wound's fibrinogen. The bi-component medium contains a collagen/thrombin component and a gelatin matrix. The swelling of the collagen granules will restrict bleeding through a tamponing mechanism, while the gelatin matrix will provide structural integrity to remain in situ. The main advantage of that form is that it can more easily be used on wet and bleeding tissues. Good results have been reported in spinal procedures [93].

N-butyl-cyanoacrylate: Histoacryl (B-Braun)

Apart from its cutaneous applications, this acrylic glue is used classically in gastroenterology to control gastro-esophageal bleeding. In spine surgery it has been used for injection of vertebral hemangiomas or malignant tumors prior to surgery in order to reduce peroperative bleeding [25, 27, 108].

Conclusions: where is the evidence?

The range of techniques available for sparing blood in spine procedures, as in other areas of surgery, is very wide and the variety of concepts is large. However, the evidence, aside from the anecdotal, is often lacking or conflicting. Controlled studies are scarce, and we do not really know if we can adapt, to spinal surgery, conclusions stemming from other surgical fields, mainly cardiac surgery, as to the efficacy of hemostatic means.

There seems to be adequate evidence showing the efficacy of most hemodynamic methods, such as hypotensive anesthesia and normovolemic hemodilution. The systemic hemostatic agents show fragmented and conflicting evidence as to their effectiveness in spine surgery. A Cochrane review of antifibrinolytic drugs in elective surgery has found good evidence to support the use of aprotinin in cardiac surgery and found trends for the effectiveness of tranexamic acid and epsilon aminocaproic acid, without, however, finding conclusive evidence, due to the heterogeneity and biases of many studies [48]. In elective orthopedic surgery, some reviews state that no hard data exist to support use of any fibrinolytic or other systemic drug [68]. RhFVIIa seems promising in the field of spine surgery, in light of results in other fields, but conclusive evidence should be demonstrated in spine surgery by proper randomized controlled trials. Alternative hemoglobin carriers are undoubtedly experimental products. As far as the local agents are concerned, once again, conclusive evidence is scarce and reports are mainly anecdotal. However, the realization of true randomized trials for those kinds of techniques is very difficult.

The daily, routine use of all these methods is also quite limited at the present time. Several surveys have shown that, outside of cardiac surgery, regular use of any blood-sparing method is infrequent [41, 54]. Lack of familiarity is the first reason quoted for their infrequent use [54]. Techniques (hemodilution, cell salvage, etc.) are more frequently used than pharmaceuticals, and there is a considerable variation among different countries [34].

Blood sparing in spine surgery is important, and it clearly appears that, contrary to other orthopedic and surgical fields, it has been understudied, with the current practice being more based on beliefs than on evidence.

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