

Review Article

Blood Loss and Massive Transfusion in Patients Undergoing Major Oncological Surgery: What Do We Know?

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Patients with solid malignancies who were not candidates for tumor resections in the past are now presenting for extensive oncological resections. Cancer patients are at risk for thromboembolic complications due to an underlying hypercoagulable state; however, some patients may have an increased risk for bleeding due to the effects of chemotherapy, the administration of anticoagulant drugs, tumor-related fibrinolysis, tumor location, tumor vascularity, and extent of disease. A common potential complication of all complex oncological surgeries is massive intra- and postoperative hemorrhage and the subsequent risk for massive blood transfusion. This can be anticipated or unexpected. Several surgical and anesthesia interventions including preoperative tumor embolization, major vessel occlusion, hemodynamic manipulation, and perioperative antifibrinolytic therapy have been used to prevent or control blood loss with varying success. The exact incidence of massive blood transfusion in oncological surgery is largely unknown and/or underreported. The current literature mostly consists of purely descriptive observational studies. Thus, recommendation regarding specific perioperative intervention cannot be made at this point, and more research is warranted.

1. Introduction

Surgical oncology, perioperative medicine, and anesthesia for oncological care have been evolving over the last four decades. Aggressive chemoradiation regimens, newer and bolder surgical techniques, effective anesthesia modalities, and impressive intensive care medicine strategies have facilitated tumor resections, which were considered difficult or unadvisable in the past [1–4]. Thus, patients with large hypervascularized tumors or cancers encasing major blood vessels are now considered acceptable surgical candidates [4]. One of the consequences of performing surgery in such patients is the risk of significant intra- and postoperative blood loss. When bleeding occurs unexpectedly and uncontrollably in the perioperative period, there is a sharp increase in mortality [5, 6].

It has been suggested that patients with cancer are more likely to be transfused with blood products than noncancer patients [7]. Moreover, an unknown percentage of these patients are at risk for massive blood transfusion, which is

commonly defined as the transfusion of more than 10 units of packed red blood cells in a 24-hour period [8]. Massive blood transfusions during oncological surgery can be anticipated or unexpected. In the former situation, since anesthesiologists, surgeons, and the blood bank services are aware of the possibility of massive blood transfusion, precautions are taken to minimize blood loss and maximize efficiency of blood product availability and administration. Several authors have investigated the use of controlled hypotension, preoperative tumor embolization, temporary aortic occlusion, and the administration of antifibrinolytic therapy to decrease blood loss and subsequent blood transfusions [7, 9–14]. Unanticipated cases of massive blood loss necessitate immediate control of surgical bleeding and measures to promptly evaluate the hemostatic defect. Managing this critical event effectively requires understanding the physiology of the coagulant and fibrinolytic systems, expeditiously managing the metabolic and hemodynamic milieu, maintaining normothermia, and coordinating care with the blood bank services to assure appropriate blood product supply in a timely manner.

In the present manuscript, we will review the literature on massive blood loss and massive blood transfusion during the perioperative period of major oncologic surgery.

2. Why Cancer Patients May Bleed Excessively during Surgery?

Most bleeding associated with surgical procedures is due to poor surgical hemostasis, also known as “silk deficiency” [15]. However, patients with cancer may also have other factors that contribute to significant perioperative bleeding.

It is well known that hematological and nonhematological malignancies activate the blood coagulation system through the release of procoagulant factors, activation of the antifibrinolytic pathways, and the creation of an imbalance between pro- and antiinflammatory cytokines, which favor the production of peripheral clots in the majority of patients [16, 17]. This procoagulant state may also continue into the postoperative period [18].

However, some patients may actually have an increased tendency to bleed excessively due to the effects of chemotherapy agents (anemia, thrombocytopenia, and endothelial system dysfunction), the administration of anticoagulant drugs (warfarin and unfractionated or low-molecular-weight heparin) to prevent the formation of deep vein thrombosis, increased fibrinolysis as in men with prostate cancer, and certain metastatic diseases [19, 20]. The incidence of preoperative thrombocytopenia is rare in patients having nonemergent oncological surgery. For example, thrombocytopenia defined as platelet count lower than 100,000 can be found in only 1% of the patients undergoing liver resection for primary or metastatic liver tumors [21]. It is well known that although patients with liquid tumors may have thrombocytopenia, they do not always demonstrate a clinical hemostatic defect. If such a patient presents for a surgical procedure, perioperative care involving excessive bleeding should be based on an objective assessment of the hemostatic function (standard and advanced hemostatic function tests) and the administration of appropriate agents (pharmacological and blood products) to correct the defect rather than a regimen-based transfusion practice to meet specific laboratory goals [22].

Patients with cancer are at risk for significant bleeding due to tumor-related factors such as proximity or invasion of major vascular structures or hypervascularization of the cancerous tissue itself [17, 18]. Lastly, it is also well known that major tissue trauma as observed in extensive oncological surgery may alter the functional equilibrium between soluble plasma fractions, erythrocytes, leukocytes, platelets, and the fibrinolytic system. This imbalance in hemostatic function may contribute to a significant coagulopathy, especially in conditions such as prolonged hypotension, hypoxemia, ischemia, massive bleeding, and acidemia. Massive bleeding and prolonged hypotension have been associated with thrombocytopenia, abnormal clotting times, and low circulating levels of fibrinogen, suggesting a clinical condition of consumptive coagulopathy [23, 24]. Hypoxemia, which may be seen during thoracic oncologic surgery (one lung ventilation) or after excessive fluid resuscitation, activates the

fibrinolytic system directly via effects on endothelial cells and indirectly by the release of catecholamines [25, 26]. Ischemia as seen during a prolonged period of hypotension or long tourniquet times (during limb surgery) is also known to induce fibrinolysis through the systemic release of tissue plasminogen activator (tPA) [27]. Metabolic acidemia as encountered during hemorrhagic shock and/or excessive resuscitation with saline solution may also have significant effects on the coagulation system. This phenomenon has been shown in experiments in which hydrochloric acid (HCl) added to blood obtained from patients and titrated to a pH of 7.0 caused inhibition of thrombin propagation and a decrease in the activity of the Xa/Va, which was observed as prolonged clotting times on standard coagulation tests and abnormal patterns on thromboelastography [28, 29]. Finally, dilutional thrombocytopenia, especially after massive blood transfusion and excessive administration of isotonic crystalloid solutions, is a common cause of perioperative coagulopathy [30].

In summary, solid tumor cancer surgery is usually associated with a predominant hypercoagulable state in the perioperative period; however, after extensive (tissue trauma) surgery, excessive volume replacement, hypothermia, hypotension, or acidemia, a shift towards dilutional coagulopathy with or without consumptive coagulation disorder can be expected.

3. Oncologic Surgery Procedures at Risk for Massive Blood Transfusions

3.1. Nephrectomy with Inferior Venous Cava Thrombectomy. Renal cancer has an incidence of about 3.1% in the adult population [31]. Renal cell carcinomas (RCCs) have a tendency to invade the venous system: first into the renal vein and then advancing into the inferior venous cava (IVC) as the disease progresses. RCC extension into the IVC has been reported in between 4% and 19% of the patients [32, 33]. According to the extent of their invasion into the IVC system, these tumors are classified into 4 categories, level I: tumor thrombus extending in the renal vein or for less than 2 cm into the infrahepatic segment of the IVC; level II: tumor thrombus extending into the IVC to below the hepatic vein; level III: tumor thrombus extending into the suprahepatic segment of the vena cava; level IV: those progressing into the right atrium [34].

Surgery remains one of the main therapeutic modalities for patients with localized RCC as well as in those with invasion of the renal vein and/or the IVC system. The degree of surgical aggressiveness depends on the level of the thrombus extension. Radical nephrectomy with infra- or supra-diaphragmatic IVC thrombectomy is the surgical options for patients with IVC tumor thrombus [35]. The surgical approach for those patients with RCC extension into the liver may vary and may involve a nephrectomy combined with a partial liver resection [36]. Concomitant splenectomy may also be required in about 2% to 8% of these patients [37].

Surgical approaches for caval thrombectomy have a high risk of significant blood loss and the subsequent need for a massive blood transfusion. Reported estimated blood loss

TABLE 1: Type of surgery, blood loss, and blood transfusion.

Type of surgery	Range of blood loss (cc)	Range of PRBCs units
Spine tumors [38–43]	400–12,100	2–10
Sacral tumors [44–46]	3,000–37,000	0–43
Hemipelvectomy [47–50]	400–12,100	0–134
Total pelvic exenterations [47–50]	900–9,500	0–18
Nephrectomy with IVC embolectomy [37, 51–55]	200–16,000	0–91
Liver and multivisceral resection [12, 56–62]	200–>5,000	0–44
Extrapleural pneumonectomies [63–65]	900–65,00	0–18

Table 1 illustrates ranges of blood losses and PRBCs of transfused units reported in the literature.

ranges from 200 cc to 16,000 cc and mainly depends on the patient's age, tumor size, the level of vascular invasiveness, and factors inherent to the surgical procedures itself such as total versus partial nephrectomy, duration of surgery, pre-operative renal artery embolization, use of traditional or minimal invasive cardiopulmonary bypass, and surgeon experience [36, 37, 51–54, 66–68]. Two observational studies demonstrated an increased rate of blood loss in patients with a level III or IV caval tumor thrombus, and in whom cardiopulmonary bypass with or without hypothermic arrest was used during the thrombectomy [69, 70]. Notably, the use of hypothermia increases the risk of coagulopathy and subsequent bleeding [68].

Fifty to 100 percent of the patients undergoing radical nephrectomies followed by IVC thrombectomy are transfused with packed red cell (PRBCs) [68, 71]; however, the exact incidence of patients having massive blood transfusion is unknown. The reported number of PRBC units transfused varies significantly (from 0 to 91), as does the time period over which the transfusions are administered in the perioperative period [37, 51–55] (Table 1). This is due to the fact that some authors have reported “perioperative” blood transfusions without clear specifications about timing parameters, while others have only published the number of units administered during the intraoperative and postoperative periods or during intensive care unit admission.

Collectively, nephrectomies in association with vascular resection and reconstruction procedures have an increased risk of blood loss and perioperative blood transfusions. The anesthesiologist participating in those procedures should be aware of the risks of extensive hemorrhage and take all necessary measures to minimize the onset of coagulopathies and blood loss, mainly in tumors with level III/IV extension and in those that extend to adjacent organs.

3.2. Extrapleural Pneumonectomy for Malignant Pleural Mesothelioma. Malignant pleural mesothelioma (MPM) is a rare and highly invasive cancer that originates in the pleural surface (90%) or in the extrapleural region (10%). Radiation, chemotherapy, and surgery, usually used in combination, are preferred treatment options for MPM. However, surgery is associated with a high morbidity (60–63%) and mortality (6.75–14%) [63, 72, 73].

Extrapleural pneumonectomy (EPP) has been performed for more than four decades in patients with MPM. One of the

potential intraoperative complications of EPP is hemorrhage, which is associated with a high rate of perioperative transfusions (approximately 90%) [72, 74]. Surgery-associated hemorrhage complicates the postoperative period, frequently requiring reoperation for control of surgical bleeding [72, 73]. More importantly, the administration of PRBCs is a risk factor for the development of postoperative complications and poor survival [63]. Investigators from our institution studied the role of aprotinin in intraoperative blood loss in patients with mesothelioma undergoing extrapleural pneumonectomy. Despite the trial being interrupted due to withdrawal of aprotinin from the market by the manufacturer, the authors reported that aprotinin decreased blood loss compared to placebo [64] (Table 2).

The exact incidence of massive blood transfusion is also largely unknown for EPP, but two observational studies indicated that approximately 10% of the patients who underwent EPP received 10 or more units of PRBCs postoperatively, and 16% of the patients received nonPRBC products perioperatively [63, 65] (Table 1).

In summary, EPP for MPM is an aggressive surgical modality, which is associated with significant morbidity and mortality. Those participating in the anesthesia and postoperative care of these patients should be conscious of the possibility of massive bleeding and blood transfusions along with a high rate of re-operations.

3.3. Hemipelvectomy for Sarcomas or Metastatic Disease. Hemipelvectomies are surgical procedures that involve the removal of the entire hemipelvis or affected hemipelvis (partial hemipelvectomy) only. The procedure may also involve resection of the ipsilateral lower extremity (external hemipelvectomy or hind-quarter amputation) or a limb sparing procedure (internal hemipelvectomy) [75]. Postoperative mortality varies from 0 to 8% [76–84]. As expected, intraoperative hemorrhage can be significant during these procedures with reported blood loss ranging from 400 cc to 12,100 cc [80, 82, 83, 85–89].

Blood transfusions are almost always required in the perioperative period of hemipelvectomies; however, the literature is still unclear about the exact rate of massive blood transfusion. A retrospective study of 160 hemipelvectomies reported that the average number of units transfused intraoperatively and during the first 2 days after surgery was 13.4 (range 0–139) units. Another observational study reported

TABLE 2: Perioperative interventions targeted to reduce blood loss during major oncological surgery.

Type of surgery	Anesthetic interventions	Surgical interventions
Spine tumors	Antifibrinolytics	Surgical hemostasis
	Controlled hypotension*	Preoperative tumor embolization
Sacral tumors	Antifibrinolytics	Surgical hemostasis
		Preoperative tumor embolization
		Aortic balloon occlusion-Iliac artery ligation
Hemipelvectomy	Antifibrinolytics	Surgical hemostasis
		Vascular control
Nephrectomy with IVC embolectomy	Antifibrinolytics	Surgical hemostasis
		Correction of hypothermia after CPB
Liver and multivisceral resection	CVP < 5 cm H ₂ O**	Surgical hemostasis
	Antifibrinolytics	Preoperative tumor embolization
		Vascular control
Extrapleural pneumonectomies	Antifibrinolytics	Surgical hemostasis

*Controlled hypotension has fallen in disfavor of many anesthesiologists due to its possible association with postoperative visual loss. **This practice has also been questioned due to the poor correlation between central venous pressure and central volume status.

a median transfusion rate of 7 PRBC (range 0–44) units perioperatively [90]. The intra- and postoperative blood transfusion requirements appear to be related to the type and extension of surgical reconstruction. For instance, in those procedures where pelvic stability was maintained, the average number of units transfused was 5; in sharp contrast, 17 units were administered to those patients in whom pelvic stability was not the surgical goal [91].

Total pelvic exenterations (TPEs) defined as the removal of all pelvic organs, including the rectum, bladder, and reproductive organs, have traditionally been performed as curative or palliative surgery in patients with locally advanced primary or recurrent pelvic malignancy [92]. TPEs are associated with significant perioperative morbidity (38.4%–70%) and a reported mortality rate lower than 5% in recent publications [47, 48, 93–98].

Despite recent surgical advances, significant blood loss during and after TPEs is still frequent. The rate of transfusion has been reported to be as high as 82% [48]. Several reports demonstrate that the estimated blood loss ranges between 900 cc and 9,500 cc (Table 1). However, not all studies report the amount of PRBCs transfused [47–50]. From those studies that have reported the amount of blood transfused, it can be concluded that the number of units PRBCs transfused ranges from zero to 18 [50]. Hence, an unknown number of patients are still receiving massive blood transfusions.

Collectively, a large number of patients undergoing extensive pelvic oncological surgeries are transfused with blood products in the perioperative period, some in large quantities. Thus, anesthesiologists should be prepared to face the clinical challenges associated with massive blood transfusions.

3.4. Liver Resections and Combined Multivisceral Oncologic Surgery. Hepatocellular carcinoma (HCC) is the third most common malignancy of the gastrointestinal tract after colorectal and pancreatic cancer [31]. However, most common tumors of the liver remain metastatic, generally from distant

areas of the gastrointestinal tract. The curative therapies available for HCC and metastatic liver diseases include ablative surgery, liver resection, and liver transplantation. Liver resection procedures may involve localized tumorectomies, wedge resection, left or right trisectionectomies, bisegmentectomies, and left or right hepatectomies. Complex resections requiring total vascular exclusions, tumor thrombectomies, and venous-venous bypass are not uncommon in patients with vascular tumor invasion of the portal vein or IVC [99].

The overall rates of morbidity and mortality in patients undergoing complex liver resection are less than 40% and 10%, respectively [56–58, 100, 101]. Blood loss still remains a significant concern after liver resection with approximately 33%, 35%, and 37% of the patients having a blood loss higher than 5,000 cc, 2,000 cc, and 1,000 cc, respectively [58, 102, 103]. The largest observational study to date reported an average estimated blood loss of 871 cc [21]. Understandably, hemorrhage and blood transfusion during liver resections have an important impact on postoperative morbidity and mortality [21, 102, 104]. For instance, blood loss higher than 800 cc is an independent risk factor (odd ratio 1.907) for postoperative morbidity after liver resection [57]. Katz et al. have also reported that estimated blood loss of more than 1 L was an independent predictor of overall survival (odds ratio –2.2), recurrence free survival (odds ratio –1.7), and disease-specific survival (odds ratio –2.3) [103]. Moreover, the authors described a “dose-response” relationship between estimated blood loss and disease-specific survival [103].

Anesthetic and surgical techniques have evolved to decrease intraoperative blood loss and develop conservative strategies for transfusion thresholds [59, 105–107]. For instance, the risk of significant intraoperative and postoperative bleeding increases during open complex liver resections as compared to laparoscopic resection. Ker et al. reported that the mean blood loss during laparoscopic resections was 138 cc versus 1174 cc in the open resections [108]. Another factor associated with blood loss is the type of liver resection;

those involving 3 or more segments are associated with significantly more bleeding (odd ratio 3.035) [59]. Bleeding from the middle hepatic vein also appears to be a risk factor for massive bleeding during liver resection [102]. Thus, vascular control is essential in large and complex resections. Of the several techniques described to minimize blood loss, most are equally effective [109, 110].

The pressure within the hepatic sinusoids is considered a predictive factor for intraoperative blood loss. This notion was supported by an early study by Jones et al. who demonstrated that maintaining central venous pressures lower than 5 cm of water was associated with significantly less bleeding (median 200 cc) compared to a pressure higher than 5 cm of water (median blood loss 1,000 cc) [12] (Table 2). However, our own experience indicates that open liver resections can be safely done without central venous pressure monitoring. Other anesthetic maneuvers helpful in reducing blood loss during liver resections include volume restriction prior to specimen resection, reverse Trendelenburg position, epidural analgesia, and systemic infusion of nitroglycerin. Using a combination of epidural blockade and systemic nitroglycerine infusion, Rees et al. reported a perioperative morbidity and mortality of 10% and 0.7%, respectively [111]. Anti-fibrinolytics have also been used to decrease blood loss and transfusion during liver surgery, but results have been controversial [13]. In a randomized controlled trial, Wu and collaborators demonstrated that tranexamic acid reduced blood loss and transfusion in patients undergoing liver tumor resections [14]. Similar results were also reported in another randomized controlled trial in which patients were treated with either aprotinin or placebo [112]. Unfortunately, the clinical use of aprotinin has been questioned due to an increased incidence of renal failure, stroke, and myocardial infarction; aprotinin has since been withdrawn from the US market [113].

The rate and amount of PRBCs transfused in patients undergoing liver resections ranges between 8.7% and 85.7% and from 0 to 24 units, respectively [12, 56–60]. In a large series of patients, Katz et al. reported that only 18% of patients received blood transfusion [103]. The rate of postoperative transfusion has been reported to be as high as 24% with a reoperation rate from bleeding of 0.4% to 5.8% [114, 115]. As with other surgical oncological procedures, the actual rate of massive blood transfusion intra- and/or postoperatively is largely unknown or underreported. However, an observation study by McCall showed that the rate of massive blood transfusion defined as 10 or more units was 1.7% in liver resections.

Interestingly, the use of fresh frozen plasma has been reported to be as high as 100% during liver resection with 13% of these patients receiving four or more units [21, 58]. The largest percentage (40%) of fresh frozen plasma transfused in the perioperative period of liver resection occurs within the first 48 hours [115]. However, the routine administration of this blood product is not justified during routine liver resections, except in cases of significant coagulopathy [58].

Multivisceral operations are usually performed on patients with locally advanced pancreatic cancer, gastric cancer,

or retroperitoneal sarcomas in order to achieve negative resection margins and thus a potential cure [116, 117]. The most common of these surgeries is perhaps the Whipple procedure or duodenal pancreatectomy. Sometimes these procedures also involve total pancreatic resection with venous and arterial vascular dissection and reconstruction followed by liver resections due to metastatic disease [118–120]. Other procedures include gastrectomies with resection of adjacent organs such as spleen, gallbladder, liver, and small and large bowel [61].

As expected, multivisceral operations may be associated with significant risk of bleeding and blood transfusions. The blood loss in these procedures ranges from 300 cc to 5,000 cc [117, 121]. In contrast to liver resection, most blood transfusions in multivisceral procedures are usually administered intraoperatively, and as expected, extensive procedures involving additional organs/structure are associated with the largest number of transfusions (0–44 units) compared to palliative procedures (0–15 units) or standard resections (0–35 units) [61, 62].

In summary, liver and multivisceral resections are among the most common oncological procedures in which massive bleeding and transfusion may occur intra- or postoperatively. More importantly, blood loss and transfusion of blood products have a significant impact on postoperative morbidity and mortality.

3.5. Oncological Spine and Sacral Surgery. Several different surgical procedures are performed for the treatment of metastatic spine tumors; they include combined anterior-posterior vertebrectomy, multisection vertebral resection, and spinal instrumentation and fusion [38, 122–124]. The overall morbidity of these procedures ranges from 14.3% to 36% [39–41, 125]. Major blood loss is also a serious concern during extensive spine procedures, and a particular challenge is the resection of spinal metastasis from renal cell carcinomas or other hypervascularized tumors [126, 127].

Different observational studies have reported an average blood loss ranging from 1,360 cc to 3,145 cc during corpectomies or en bloc tumorectomies of the thoracic or cervicothoracic region. However, massive blood loss has also been reported with maximum blood losses of 21,000 cc [38–43] (Table 1). Combined anterior-posterior thoracic corpectomies are associated with a higher blood loss than anterior or posterior only approaches [41]. The rate of transfusion in these procedures varies widely. However, most studies report that the rate ranges from 17% to 70% [43]. The median number of PRBC units transfused during lumbar surgery for metastatic disease is 2 units; however, an unknown number of patients still receive more than 10 units of packed red cells [42].

Several pharmacological and nonpharmacological interventions have been used in an attempt to reduce blood loss during surgery for spinal tumors. Some authors have recommended preoperative embolization of spinal metastasis to reduce intraoperative blood loss [9, 10]. Intraoperative controlled hypotension was commonly implemented in the past to diminish blood loss; however, this technique has been questioned due to the risk of postoperative visual loss in long

and complex spine procedures [128]. Antifibrinolytic therapy including aprotinin, tranexamic acid, and epsilon-aminocaproic acid has been shown to decrease blood loss in total knee replacements, scoliosis surgery, and cardiac surgery [129–131]. Bednar et al. reported their experience using tranexamic acid to minimize operative blood loss during a single-surgeon intralesional tumor excision and instrumentation. Although they found a reduction in blood loss with tranexamic acid, the findings of their retrospective review were not statistically significant [132] (Table 2).

Surgical procedures for resection of primary or metastatic sacral tumors are an effective therapeutic option for long-term disease control and cure [133]. Morbidity after sacral tumor resection remains high [44, 134]. In a large series of patients, Fourney et al. reported a 30-day complication rate of 61%. Unfortunately, significant intra- and postoperative blood loss (due to anatomic characteristics of the sacral region and the size of the tumors) is a common complication with average blood loss estimated between 2,922 cc and 6,300 cc [45, 46, 135]. Remarkably, almost 40% of the patients had a blood loss greater than 3,000 cc with a maximum blood loss of 37,000 cc [44, 45]. Risk factors associated with an excessive blood loss are hypervascularity (odds ratio 2.281), tumor location at or cephalad to S2 region (odds ratio 3.84), and tumor volume greater than 200 cm³ (odds ratio 3.381) [45, 136]. Different pre- and intraoperative interventions have been described to reduce bleeding and related morbidity. A few authors have successfully utilized aortic balloon occlusion to avoid significant bleeding [46, 137, 138]. Others have reported encouraging results with preoperative tumor embolization, ligation of both internal iliac vessels, and staged surgery [139–141].

As expected, transfusion of PRBCs and other blood products is common during sacral surgery. Two retrospective studies including 19 and 24 patients reported that the average number of PRBCs transfused intraoperatively was 10.2 units and 11.5 units, respectively, with a maximum amount of 43 transfused units in one of the studies [134, 141]. In contrast, in another observational study of 60 patients, the average number of transfused units was 5.2; however, these patients underwent preoperative tumor embolization [140]. It is important to note that the highest number of PRBCs transfused was in patients undergoing hemisacrectomies, with 75% of them receiving 10 or more units of blood [134, 139]. Thus, massive blood transfusions are common in patients undergoing sacrectomies.

Collectively, resection of spine and sacral tumors presents a formidable challenge to the anesthesia team. As massive bleeding and blood transfusions are extremely common, it would be prudent for anesthesiologists to discuss different perioperative interventions and strategies to reduce bleeding with the surgical team.

4. Conclusion

Patients undergoing major oncological surgery are at risk for severe bleeding and massive blood transfusion due to tumor characteristics, preoperative chemoradiation, anatomic features of the surgical area (vascular proximity), complexity

of resection, duration of surgery, perioperative hypothermia, metabolic derangements, and intraoperative dilutional coagulopathy (blood transfusions and fluid administration). It is therefore crucial for the anesthesia team to have a clear understanding of all those factors and to work closely with a meticulous, efficient, and experienced surgical team to delineate perioperative interventions (tumor embolization, operative staging, and/or pharmacological interventions) targeted to minimize perioperative blood loss (Table 2).

Unfortunately, the current literature review is unclear about the exact incidence of massive blood transfusions in major oncological surgery. Furthermore, there may be a bias toward underreporting due to lack of clear definitions of the “perioperative period” in this context and, perhaps, disinterest in the medical community on this topic.

The relationship between immune competence during the perioperative period and recurrence-free survival after a curative resection is becoming a topic of interest. It is well known that allogeneic transfusions induce immune suppression and are an independent predictor of morbidity and mortality [142–144]. The effect of “anesthetic techniques and perioperative management” on positively influencing the balance between inflammation and immune competence is an intriguing avenue for future study. Thus, we urge perioperative clinicians and researchers to start reporting data on massive blood transfusions and to study its impact on clinical outcomes in patients undergoing major oncological surgery.

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