Management of complex spine surgery

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Purpose of review
The main objective of this article is to present the updated data regarding the perioperative management of patients undergoing major spine surgery in an era where the surgical techniques are changing and there is a high demand for these surgeries in older and high-risk patients.

Recent findings
Preoperative assessment and stabilization is now more structured protocol and it is based on a multidisciplinary approach to the patient. The Enhanced Recovery After Surgery (ERAS) programs and the Perioperative Surgical Home on major spine surgery are not yet fully evidence based but it seems that the use of a perioperative optimization of patients and use of a drugs' bundle is more effective than using single drugs or interventions on the postoperative pain reduction and faster recovery from surgery. Fluid and pain-control protocols combined with an accurate blood management represent the key to success.

Summary
A tailored approach to patients undergoing major spine surgeries seems to be effective improving the outcome and quality of life of patients. Future studies should aim to understand which elements of the ERAS can be improved to allow the patient to have a long-term good outcome.

Video abstract
http://links.lww.com/COAN/A45

Keywords
blood losses, enhanced-recovery after surgery, major spine surgery

INTRODUCTION

Major spinal surgery procedures have increased significantly in the last two decades [1,2] for three main reasons: the increased age demographic of the general population, the introduction of minimally invasive methods including percutaneous procedures, and improved outcomes including reduced hospital stay and return to desirable lifestyle. Lumbar and cervical fusion are the main reported procedures on the spine and these numbers seems to be significantly increase because of life style variations [2,3]. Although spine fusions are now considered minimally invasive techniques, the aggregate costs related to these surgeries has increased since the complexity of spinal involvement and number of levels to be fused have increased [4]. A recent meta-analysis [5] on the effectiveness of minimally invasive techniques for lumbar spinal stenosis has revealed that there was no difference in terms of improved outcome for the most commonly used surgical techniques. Other important factors to be considered in complex spinal surgeries include length of the procedure and anaesthesia time, prolonged prone positioning and blood loss which can contributors to postoperative adverse events.

Thus, the anaesthetic management of such complex spine procedures starts from the preoperative assessment and improvement of physical status and optimization, example of which can be seen in the recently launched BiBo course [6], continues with the intraoperative management of fluid and blood losses and avoiding complications (such as perioperative visual loss) and moves beyond the operative period to management of postoperative pain. The purpose of this review is to investigate new evidence from the recent literature and introduction of new translational studies that are directed to improve the outcomes after complex spine surgery in adult patients.

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KEY POINTS

- The anaesthetist should guide the patient in a focused and tailored multidisciplinary evaluation before undergoing major spine surgery. PSH represent a one-stop-shop where this can happen.
- The ERAS protocols are still not clearly defined for these surgeries but it seems that they work when applied as bundles and when a multimodal pain control is initiated.
- Perioperative complications can be avoided through a careful monitoring and management of hemodynamic.

PREOPERATIVE OPTIMIZATION

The application of a standardized screening method to optimize patients before surgery is a milestone to reduce the risk of complications and reduce negative outcomes related to major spine surgery [7]. Given the complexity of these patients and coexisting comorbidities, a wide range of medical specialties should be involved in the preoperative assessment for complex spine surgery. Different standardized protocols [7] have been proposed to evaluate and optimize the patient, but the focus seems to be including an expert anaesthetist leading the team that plans the proper path for each patient. The different steps included in the evaluation are: a full functional status assessment including pain score as quality of life and disability scales; the pulmonary status including pulmonary function tests in case of mild to severe pulmonary problens and severe scoliosis; preoperative cardiac testing including echocardiogram and cardiac functional imaging as the revised cardiac risk index (RCRI) is not able predict cardiac morbidity in patients undergoing major spine fusion surgery. Preoperative testing and optimization decisions, previously based on the RCRI, may need to be revised to include more frequent functional cardiac imaging and more aggressive implementation of pharmacologic modalities that may mitigate cardiac morbidity, similar to the preoperative evaluation for major vascular surgery [8]. This is especially true for spine procedures because immediate postoperative anticoagulation or continuation of antiplatelet therapy in perioperative period may face resistance by the surgical team to decrease risk of postoperative bleeding.

A standard set of preoperative studies are suggested to complete the preoperative evaluation including radiologic evaluations and measurements of pelvic parameters and angles of major and minor curves in scoliotic patients. It is also important to investigate presence of osteoporosis and all patients should receive a dual-energy X-ray absorptiometry (DEXA) and in case of proximal junctional kyphosis, they should be considered for cement augmentation [8].

All these preoperative studies and evaluations should be used to give to the patient and the surgical team the correct informations on how to manage perioperatively and perioperatively the patients' journeys. This standardized approach will include not only the preoperative assessment to optimize the patient but it will cover the intraoperative issues specific for each case and the postoperative management including possible prolonged ventilation, weaning, and extubation [7]. The rationale of using a standardized approach is to achieve better outcomes and reduce costs.

More recently, the American Society of Anesthesiology has launched the model of perioperative surgical home (PSH) [9] where the patient's experience of care is coordinated by a Director of Perioperative Services (usually an anaesthetist), a group of perioperative physicians including surgeons, internists, cardiologist, radiologists, and supportive personnel which constitute an interdisciplinary team. The goal of the Perioperative Team is to improve the operational efficiency, decrease resource utilization, reduce the length of stay and readmissions, and decrease complications and mortality, resulting in a better patient experience of care. This model has been actually applied in some kind of surgeries [10] with success and it is more patient than procedure-centred.

PERIOPERATIVE VISUAL LOSS

One of the most dreaded complications after spine procedures is visual loss because it has an unpredicted and overall a poor outcome [11]. Although rare accounting to an incidence of 1–10/10 000 procedures, its dramatic effect on lifestyle is what has made this complication so feared. From the three pathophysiologic mechanisms that have been described including central retinal artery or vein occlusion, cortical blindness, and ischemic optic neuropathy, it is the latter that has been mostly described as the main mechanism for spine procedures [12].

Despite difficulties in designing a prospective study to evaluate the risk factors of ischemic optic neuropathy, in 2012 an multicentre study by postoperative visual loss study group using the American Society of Anesthesiologists (ASA) postoperative visual loss registry comparing 80 spinal fusion cases with perioperative visual loss with 315 controls without this complication, showed that the risk factors included male sex, obesity, using a Wilson frame, greater estimated blood loss, prolonged anaesthetic duration, and lower percentage of colloid use [13].

More recent retrospective data analysis of 2 511 073 cases of thoracic, lumbar, and cervical fusion confirmed that ION is still the leading cause of visual loss in spine fusion cases and through a multivariate analysis showed that age, male sex, obesity, and blood transfusion were the factors associated with perioperative ION. In this study, blood transfusion was counted as a surrogate for blood loss [14]. The data source for this study was National Inpatient Sampling (NIS), which lacks intraoperative data including blood loss, fluid administration, positioning, length of procedure, and anaesthetic technique. This study also confirmed that there has been a relative decrease in the number of cases of ION, despite an increase in the number of spine fusion cases but no significant change in the rate of retinal artery occlusion, suggesting a different physiopathologic mechanism for each. It may seem that this may have been a result of special attention to the change practice to avoid identified risk factors. However, an editorial on the study argues this conception. It is obvious that in the time frame of the original study the age has grown, patients have become obese, and there has not been a dramatic difference in the sex except for a small decrease of 3% in the male population which could not explain the decrease in overall incidence of ION. Also, the trend in the drop of ION had started before the practice advisories recommended. This editorial has reiterated the need for continued research to find a causal relationship because the incidence even within those who may have a combination of proposed risk factors is still very low.

The ASA registry, data from case reports, and expert opinions were the source of a practice advisory by ASA in 2006. This advisory was reviewed and updated in 2012 [15]. The main recommendations were on close monitoring the blood pressure, and hematocrit, with optimizing these values and hemodynamic status, avoiding pressure on the eye and neutral positioning of the head, including colloids in fluid regiment, staging long spine procedures, and early evaluation and urgent ophthalmologic consult if there is any concern.

Despite the decrease in the incidence that we have seen, recommendations on the anaesthetic management to decrease the chance of developing perioperative visual loss is still being reviewed and published [16].

BLOOD AND COAGULATION MANAGEMENT

Managing preoperative anaemia is one of the pillars to reduce 30-day mortality and morbidity [17]. Recent trials [18,19] have shown benefit to postpone the procedure when the patient was found to be anaemic for treatment with intravenous iron, vitamin B12, folic acid, and erythropoietin. The authors found that simple administration of vitamin B12, intravenous iron, and folic acid was as effective and less expensive than erythropoietin and safer than a transfusion of packed red blood cells.

The use of antifibrinolytic drugs has been debated for years. Tranexamic acid has been used in different studies to reduce blood losses during spine surgery. There are no definite protocol and dosages but it seems that a total dose of 1 g, administered intraoperatively, is sufficient for most adult patients [20–22].

In case of massive or diffuse bleeding, a point-of-care testing as thromboelastography and thromboelastometry will provide the correct information to direct a goal-directed transfusion therapy [23].

The most challenging problem seems to be represented by patients scheduled for complex spine surgery treated with the new anticoagulants such as direct thrombin (dabigatran) and factor Xa inhibitors (rivaroxaban, apixaban, and edoxaban). Patients treated with these drugs should only be operated after discontinuation of medications or bridging to low molecular weight heparin. Pollack *et al.* published preliminary data of 90 patients (total of 300 planned) of the 'A Study of the RE-VERSal Effects of Idarucizumab on Active Dabigatran' (RE-VERSE AD study), which is an ongoing multicentre prospective cohort study where the reversal of dabigatran is evaluated in patients with serious bleeding or those who require emergency intervention. They demonstrated that Idarucizumab completely reversed the anticoagulant effect of dabigatran within minutes without major safety concerns [24].

Mechanical ventilation modes are also affecting intraoperative surgical bleedings. A recent study from Pollack *et al.* [25] demonstrated that patients undergoing lumbar fusion ventilated in pressure-controlled ventilation have less surgical bleeding than patients ventilated in volume-controlled mode.

ENHANCED RECOVERY AFTER SURGERY

Discussions regarding enhanced recovery after surgery (ERAS) pathways started in the 1990s and it was initially introduced by Kang [26]. He demonstrated that patients' outcome can be improved by applying evidence-based perioperative principles designed to prepare patients for surgery and reducing the impact of surgery.

ERAS is defined as a multimodal perioperative care pathway designed to achieve early recovery for

patients undergoing major surgery. The key elements of ERAS protocols include preoperative assessment and optimization of the patient, multimodal approach to analgesia, optimization of nutrition, and early mobilization.

Over the past decades, ERAS pathways have been implemented throughout the world across multiple surgical disciplines. In 2016, Kehlet *et al.* [27] demonstrated the importance of establishing an ERAS pathway for major spine surgery and how applying it can lead to faster recovery, reduction of the length of hospital stay, and overall costs.

Multimodal pain management

To understand and treat postoperative pain, it is necessary to understand the pathophysiological role of the different components participating in the development of pain and to determine if any modification of these components may improve the surgical outcome. Postoperative pain after spine surgery is the result of the activation of different pain mechanisms, including nociceptive, neuropathic, and inflammatory components. Most of these patients suffer from chronic pain and long-term use of opioid analgesics, all these factors contribute to add challenges to the postoperative treatment. The multimodal approach needs to address the treatment to all the different mechanisms representing a logical therapeutic approach. The goal is to optimize the postoperative pain control with a reduction in opioid consumption and opioid related side effects.

Potential perioperative nonopioid analgesics and co-analgesics that can be used in the multimodal protocol include: acetaminophen, gabapentin, NMDA receptor antagonists (ketamine or $MgSO_4$), dexamethasone, $\alpha 2$ receptor agonists, intravenous lidocaine infusion, NSAIDs, neuraxial blockade, and local anaesthetic infiltration at the site of incision.

Several clinical trials have examined the use of parenteral acetaminophen as part of preemptive multimodal analgesia with different results [28▪,29]. A meta-analysis of randomized controlled trials published in 2015 showed that parenteral paracetamol when used as a single dose and as a preemptive analgesic significantly reduced postoperative pain and postoperative nausea and/or vomiting [30].

There is evidence to suggest that gabapentin is well tolerated and effective in decreasing pain scores and opioid consumption when administered preoperatively between 1 and 2 h before surgery. Albeit, there is still some controversy over the optimal dosage of oral gabapentin [31,32]. Actually, it is uncertain which dosage of oral gabapentin can be considered effective and safe in the management of postoperative pain [33,34]. Higher doses (900–1200 mg) seems to be more effective than lower doses (300–600 mg) [32].

A recent study confirmed that intraoperative intravenous infusion of lidocaine improves early postoperative pain after complex spine surgery. The infusion protocol consists in a bolus dose of 2 mg/kg followed by a continuous infusion at 2 mg/kg/h. However, the perioperative administration of intravenous lidocaine, in other surgical fields, varied between the studies concerning the dose of the lidocaine bolus (100 mg or 1–3 mg /kg), the dosage used during the continuous infusion (1–5 mg/kg/h), and the duration of the infusion [35]. In the future, it would be necessary to define which is the best dose during continuous infusion of lidocaine and also when to stop it to avoid over dosage and adverse events.

Use of dexamethasone as preemptive co-analgesic in the treatment of early postoperative pain definitely belongs to the multimodal pain therapy. Most clinical trials have investigated the analgesic effect of low doses dexamethasone (<0.1 mg/kg), which shows modest analgesic effects when compared to intermediate dose of dexamethasone (0.11–0.2 mg/kg) in the reduction of pain and opioid consumption with no apparent additional benefit when higher doses were used [36,37]. Another study published by De Oliveira *et al.* [38] demonstrated that intermediate dose of dexamethasone (16 mg to 0.11–0.2 mg/kg) significantly reduced pain during mobilization but opioid consumption, pain at rest, sedation and nausea were not significantly affected.

Ketamine is a well known anaesthetic agent that has opioid-sparing analgesic properties. Several clinical studies have examined the efficiency of s-ketamine in reducing postoperative pain and analgesic consumption in spine surgery, showing that s-ketamine infusion reduces opiate consumption and it provides good postoperative analgesia with minimal side effects [39–41].

Magnesium is another NMDA receptor antagonist used as a co-analgesic in multimodal pain management. Different concentrations have been used during clinical trials, with contradicting results, in reducing postoperative opioid consumption and pain scores [42–44]. Use of magnesium sulphate was associated with lower requirements of neuromuscular blocking agents and longer recovery time but no symptoms of muscle weakness were observed [44]. Further clinical trials should give an answer if there is a place for magnesium in multimodal pain management in major spine surgery and what should be the optimal dose to be administered to minimize its possible side effects.

Table 1. List of drugs used in the ERAS multimodal pain protocols

	Time	Doses	References	Design type
Acetaminophen	Before beginning of surgery	1 g or 15 mg/kg for < 50 kg	De Oliveira *et al.* [31]	Systematic review and meta-analysis
Gabapentin	In 1–2 h before surgery	900–1200 mg	Yu *et al.* [34]	Systematic review and meta-analysis
Lidocaine	Induction Maintenance	1.5 ml/kg-bolus 1–2 mg/kg/h	Weibel *et al.* [36]	Randomized controlled trial
Ketamine	Induction Maintenance	0.5 mg/kg-bolus 10 mcg/kg/min	Loftus *et al.* [40]	Randomized controlled trial
Magnesium	Induction Maintenance	50 mg/kg-bolus over 10 min followed by 10 mg/kg/h	Shin *et al.* [44]	Randomized controlled trial
Dexamethasone	After induction	16 mg-bolus (0.11–0.2 mg/kg)	Nielsen *et al.* [39]	Randomized controlled trial
Dexmedetomidine	Before induction Maintenance	1 μg/kg-bolus 0.5 μg/kg/h	Srivastava *et al.* [45]	Randomized controlled trial
	Postoperative period for 24 h	0.5 μg/kg-bolus 0.3 μg/kg/h	Garg *et al.* [42]	Randomized controlled trial

Clinical trials regarding the use of α2 receptor agonist (clonidine and dexmedetomidine) in major spine surgery are limited. Two clinical studies published in 2016, with different primary end-points, showed that mean-pain free period was longer and that opioid requirement was decreased in the dexmedetomidine group [41,44]. Additional trials are necessary to define the optimal dose and the duration of the infusion and the role of α2 receptor agonists as a part of multimodal pain management.

Multimodal analgesia represents now the cornerstone of postoperative pain management for spine surgery [45,46]. There is enough evidence that supports many of the commonly used agents as a part of multimodal therapy. However, there is a lack of studies that incorporates all of them into clearly defined protocols or pathways. Treatment is diverse, with wide variation in the multimodal pain management [40,47–50]. A summary of the multimodal pain approach drugs is presented in Table 1.

CONCLUSION

The increasing volumes of patients undergoing major spine surgeries have placed the need for the anaesthetists to manage these patients at the same time in a standardized way but also in a tailored evaluation according to the type of surgery, comorbidities and expectancy of quality of life after surgery. A multidisciplinary approach lead by the anaesthetist, as recently suggested with the PSH model, seems to be the more effective path to optimize patients before surgery and to minimize the potential intraoperative complications. The ERAS protocols seem to be effective but there is still some lack of evidence on their use in these kinds of surgeries. The multimodal pain approach is an essential part of the ERAS pathways and it is associated with better outcomes when applied in bundles more than when a single drug protocol is used. Future research is needed to understand and develop a more evidence-based ERAS protocol for major spine surgery.

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Conflicts of interest

There are no conflicts of interest.

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- ■ of special interest
- ■■ of outstanding interest

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