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Consensus statement for perioperative care in lumbar spinal fusion: Enhanced Recovery After Surgery (ERAS®) Society recommendations

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Acronyms

CHO: Oral Carbohydrate Load

ERAS: Enhanced recovery After Surgery

GDC: Guideline Development Group

GRADE: Grading of Recommendations, Assessment, Development and Evaluation

EA: Epidural Analgesia

LOS: Length of stay

NSAIDs: Nonsteroidal Anti-Inflammatory Drugs

PCA: Patient-Controlled Analgesia

PEH: Postoperative Epidural Hematoma

PONV: Post-Operative Nausea and Vomiting

POUR: Postoperative Urinary Retention

PRO: Patient Related Outcome

RCT: Randomized Controlled Trial

SSI: Surgical Site Infection

TLIP: Thoraco-Lumbar Interfacial Plane

VTE: Venous Thromboembolism

WI: Wound Infiltration

Introduction

Popularized by Henrik Kehlet in the 1990s [1], a multimodal approach of perioperative management, including nutrition and analgesia, called “Fast-Track Surgery,” was introduced. This later developed into what is now known as Enhanced Recovery After Surgery (ERAS) program, an evidence-based approach to perioperative care, aimed to enhance recovery [2]. In 2010, the ERAS® Society was formed and has since then produced a range of consensus guidelines for several surgeries (http://www.erassociety.org). The main goals of ERAS are the improvement of surgical outcomes, reduction of complications, improved patient experience, and reduction in the length of stay (LOS) [3,4]. ERAS programs have been successfully implemented in different areas of surgery and offer results that justify the growing corpus of publications surrounding this paradigm [5].

The improved knowledge of spinal biomechanics together with the increasing age of our population, improved imaging diagnostics, technical advances (implants and minimally invasive technologies), initial training of physicians (orthopedic and neurosurgeons), as well as medico-economic and societal factors, have led to an increase in the number of lumbar fusion surgeries over the past few decades [6–10]. Furthermore, the increased complexity of these procedures increases the risk of postoperative complications and delayed recovery [11–14]. Lumbar surgery has been rated as one of the most painful procedures [15–17], and the subsequent risk of chronic pain and postoperative opioid dependence is not negligible [18,19]. There are significant practice variations across institutions and countries in the treatment and perioperative care of patients with degenerative spinal conditions [7,20]. These differences lead to varied perioperative surgical outcomes, including LOS, postoperative complication rates, and rates of functional recovery [21–25].

Therefore, there is a significant clinical and economic rationale for improving the management and outcomes of these conditions [26]. Evidence-based standardization of perioperative management of lumbar fusion patients through the implementation of ERAS protocols can lead to improved outcomes [26,27]. The literature studying the application of ERAS protocols in spinal surgery is still recent [28–30]. However, in this surgical specialty, specific evidence-based ERAS guidelines aiming to reduce perioperative stress, minimize complications, and importantly accelerate the achievement of discharge are lacking. As such, under the impetus of the ERAS® Society, a multidisciplinary, international working group of ERAS experts was formed to develop evidence-based recommendations for lumbar fusion surgery using the Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) system for rating quality of evidence and strength of recommendations [31].

Methods

Formation of the guideline development group and selection of guideline topics

The formation of the guideline development group (GDG) and the selection of guideline topics were performed following the published recommendations for the development of clinical guidelines within the ERAS® Society framework [32]. The GDG has an international representation consisting of experts involved in the practice of ERAS and spine surgery (orthopedic and neurosurgeons, anesthesiologists, dedicated ERAS nurses, epidemiologists, and physiotherapists). The GDG was notified that this first set of recommendations devoted to spine surgery would focus on lumbar fusions, effectively excluding cervical spine surgery, anterior approaches, and complex deformity procedures, particularly idiopathic scoliosis. The GDG was consulted to advise on appropriate items to be included in the guidelines, with the final decision being made by the lead authors (BD, TW, HDB). Once agreed, items were allocated to authors depending on each individual's expertise. The final paper was agreed upon by all authors.

Literature search strategy

The search strategies were created using MESH term and keywords, and searches were carried out in MEDLINE, Embase, and Cochrane Central Register of Controlled Trials (earliest on record until December 2019). No search filters were used to maximize sensitivity. Systematic reviews, randomized controlled trials (RCTs) and observational cohort studies reporting on adults (≥18 years) undergoing lumbar spinal fusion surgery related to one of the ERAS topics were included. Non-English studies were excluded. It is important to note that although a systematic search was conducted using the ERAS® Society framework [32], the purpose of this search was not to obtain a comprehensive summary of the literature, but rather to ensure that the most relevant information is captured for inclusion in the ERAS® guidelines

(Figure 1). The final included studies were carefully reviewed by the GDG, and any disagreements were resolved through group consensus. These search strategies are comprehensively detailed in the Appendix [33].

Quality assessment, data analyses, and consensus generation

The GRADE system was used to evaluate the quality of evidence and recommendations for each of the ERAS topics [31]. Recommendations are made based on whether the quality of evidence is high, moderate, low, or very low (Table 1). The strength of the recommendation is based on the balance between desirable and undesirable effects of the recommendation. Strong recommendation for an ERAS item is possible even with low quality of evidence if the risk of harm is negligible [34–36] (Table 2). In case of any disagreements in assessing the quality of evidence and grading of recommendation statements, the following procedures were performed: a) this was either resolved through consensus discussions, or b) when the disagreements persisted, by a Delphi process [37].

We were judicious when providing strong recommendations in areas where there was weak procedure-specific evidence to ensure that new nonevidence-based traditions within ERAS were not created.

Results

The electronic database search for the 22 ERAS items yielded 66,432 articles. Forty-six thousand one hundred fifty-one abstracts were screened after duplicates were removed. Two hundred fifty-six articles were included in the development of the consensus statement. There was no disagreement between the authors in the assessment of the quality of evidence and grading. Therefore, a Delphi process was not needed. Based on consensus, one ERAS item (prehabilitation) was eliminated due to very poor quality and conflicting evidence in lumbar fusion. From the remaining 21 ERAS items, 28 recommendations were made (Table 3).

Preoperative recommendations

Preoperative education & counseling

Current ERAS protocols for spinal surgery all emphasize the importance of preoperative patient education and counseling [30,38,39]. This appears appropriate given that preoperative information can influence patient expectations, and patients who receive sufficient counseling are likely to have higher levels of satisfaction than those who receive insufficient education [40]. This is especially important since lumbar surgery may be perceived to have uncertain outcomes with negative side effects and a considerable recovery period [41]. The uncertainty of outcomes can contribute to preoperative fear and anxiety, which can negatively affect recovery after surgery. Combining preoperative education with consistent written patient information materials is, therefore, also essential [42].

Within the spinal literature, a systematic review including seven RCTs demonstrated limited evidence for preoperative education, counseling, and cognitive interventions to reduce postoperative pain and length of stay [43]. Although preoperative education and counseling appears rational for lumbar spine surgery and carries a minimal risk for adverse effects, the evidence substantiating its use is unclear. Recent prognostic tools may improve shared decision making on creating a personalized perioperative treatment strategy to improve pain outcomes [44]. Further research is needed to determine the timing, mode of delivery, specific intervention, and specific patients that would benefit most from preoperative education and counseling.

Summary/recommendation

Preoperative patient education is recommended.

Quality of evidence: Low

Recommendation grade: Strong

Prehabilitation

Prehabilitation has been described as enhancing functional capacity before surgery [45] to accelerate return to function following surgery [46]. Across surgical disciplines, prehabilitation is an intervention that combines exercise, nutrition therapy, and psychological preparation. These programs have been shown to facilitate recovery in the general surgery discipline [47]. In contrast, prehabilitation has not been found to reduce LOS in orthopedic procedures such as hip and knee replacement, and for these operations, it is not routinely recommended [27].

Within the spine surgery literature, a recent systematic review of three RCTs concluded that there is insufficient evidence to ascertain whether prehabilitation improved functional outcomes [48]. Further procedure-specific research is required and should target prehabilitation interventions for specific groups of patients known to recover slowly following surgery. These include the elderly and frail patients, patients with special needs or multiple comorbidities, and patients with psychiatric illnesses.

Summary

Evidence is currently insufficient to make a recommendation on prehabilitation as an essential intervention for all patients.

Preoperative nutritional supplementation

The diagnosis of preoperative malnutrition can be achieved by using a combination of laboratory testing, anthropometric measurements, and standardized nutritional scoring systems such as the Mini Nutritional Assessment tool [49]. Low albumin, low transferrin levels, and low lymphocyte count have been associated with increased risk of surgical site infections, postoperative complications, increased length of hospital stay, 30-day readmission rates, and mortality following spinal surgery [50–55].

Although malnutrition has been well established as a risk factor for poor outcomes in many surgeries, there is a paucity of studies that evaluate whether modifying or optimizing preoperative nutritional states results in improved clinical outcomes following spinal surgery. In an RCT evaluating a multimodal nutritional management protocol, including protein, nutritional, and carbohydrate powder packs given to patients before and after lumbar spinal surgery, was associated with shorter LOS, lower incidence of electrolyte disturbances, and higher postoperative albumin levels on postoperative day 3 compared to control patients [56]. When evidence of malnutrition is detected, first-line therapy should consist of dietary advice, meal fortification with protein, and increasing the variety and taste of diet [57]. Oral nutritional supplements can also be used to improve energy and nutrient intake and have been associated with reduced LOS in hospitalized patients compared to routine clinical care [57].

Summary/recommendations

Patients undergoing lumbar fusion should undergo a preoperative nutritional assessment.

Quality of evidence: Low

Recommendation grade: Strong

Preoperative nutritional interventions should be offered to patients identified as malnourished.

Quality of evidence: Low

Recommendation grade: Strong

Preoperative cessation of smoking

Tobacco smoking is a risk factor for perioperative and postoperative complications such as pulmonary and cardiovascular complications, pseudoarthrosis, worse functional outcomes, deep vein thrombosis, delirium, morbidity, and mortality [58–65].

Preoperative smoking cessation interventions are effective in reducing postoperative complications. A meta-analysis including six RCTs concerning various elective surgeries demonstrated that each week of cessation increases the magnitude of effect by 19% [66]. A minimum period of 4 weeks of cessation is effective in reducing postoperative respiratory and wound healing complications [66–68]. Nicotine replacement therapy combined with intensive counseling was the most effective method for smoking cessation with short- to long-term benefit [69–71].

After spine surgery, it is also important to maintain smoking cessation. Continued smoking after spine surgery was associated with an increased recurrence of lumbar disk herniation [72,73], increased postoperative opioid utilization [74], and pseudarthrosis [75–77]. Smokers should be counseled about the increased risk of pseudarthrosis before surgery [77,78].

Summary/recommendation

A combined smoking cessation therapy at a minimum of 4 weeks before surgery is recommended.

Quality of evidence: Moderate

Recommendation grade: Strong

Preoperative cessation of alcohol

A systematic review of 25 case-control studies showed daily consumption of >2 units of alcohol increased the risk of postoperative complications after spinal surgery [60]. The impact of ≤2 units of alcohol on postoperative complications is less obvious. Complications associated with alcohol consumption in spinal surgery include pseudarthroses, postoperative infections, cardiopulmonary complications, postoperative ileus, delirium, bleeding episodes, and deep venous thrombosis [60,63,64,79–83].

Several meta-analyses of RCTs, including two Cochrane reviews in the orthopedic and neurosurgical population, showed that preoperative alcohol cessation interventions 4–8 weeks before surgery could reduce the risk of postoperative complications, but not mortality [79,82,84]. Alcohol cessation programs include a combination of behavioral interventions, disulfiram, vitamins, and benzodiazepines [84]. These strategies have been shown to significantly improve abstinence during the intervention period; however, these studies were limited by their small sample size [82].

Summary/recommendation

Alcohol cessation programs 4–8 weeks before surgery can reduce postoperative complications.

Quality of evidence: Moderate

Recommendation grade: Strong

Preoperative fasting and carbohydrate treatment

Fasting from midnight before induction of general anesthesia aims to reduce the volume and acidity of the stomach contents during surgery, thus reducing the risk of pulmonary aspiration [85]. However, this dogma has not been supported empirically [86–88]. A Cochrane review of 22 RCTs in elective gynecological and general surgery showed only six studies that evaluated the incidence of aspiration, and from these, no aspiration events were observed [89]. There was no difference in the volume or pH of the gastric content between patients in the fasting group compared to patients who were allowed clear fluids until 2 h before anesthetic induction [89]. The European Society of Anaesthesiology and American Society of Anesthesiology guideline recommends clear liquids (e.g., water and black coffee) may be ingested for up to 2 h and a light solid meal may be ingested up to 6 h before surgery requiring general anesthesia [87,88].

Surgical trauma results in multiple neuroendocrine responses resulting in a catabolic state characterized by increased protein breakdown and insulin resistance, leading to postoperative hyperglycemia and other physiological disturbances that may affect recovery [90]. Preoperative administration of oral carbohydrate load (CHO) has been shown to attenuate both insulin resistance and an overall catabolic state in other surgical disciplines [91]. Two

RCTs have compared the effects of CHO vs. preoperative fasting on glucose control in the spinal surgery population [92,93]; neither could prove the advantage of CHO loading. As such, the clinical benefit of CHO loading in spinal surgery remains controversial, and a specific recommendation for its routine use cannot be made.

Summary/recommendations

Clear fluid should be permitted up to 2 h and solid foods up to 6 h before the induction of general anesthesia.

Quality of evidence: High

Recommendation grade: Strong

Evidence is currently insufficient to make a recommendation on routine use of CHO load for lumbar spine fusion.

Pre-anesthetic medication

Preoperative anxiety is a common phenomenon and may lead to increased perioperative analgesic requirements [94]. Pharmacological anxiolytic strategies include the prescription of sedative or anxiolytic drugs like benzodiazepines. However, even a single dose of benzodiazepines can cause neurocognitive impairment and have sedative effects [95]. A large retrospective cohort study of 94,887 procedures of general and orthopedic surgery demonstrated that benzodiazepine use was associated with an increased risk of an adverse event postoperatively (odds ratio [OR] 1.13; 95% confidence interval [CI] 1.08–1.18) [96]. Therefore, sedative or anxiolytic drugs should be avoided to prevent the risk of neurocognitive impairment and postoperative adverse events.

Preemptive analgesia can also be applied as part of a multimodal opioid-sparing analgesia strategy. The commonly used drugs include acetaminophen (paracetamol), nonsteroidal anti-inflammatory drugs (NSAIDs), and gabapentinoids. Preoperative administration of acetaminophen and NSAIDs has been shown to decrease postoperative pain scores, is opioid-sparing, and can be administered easily in a cost-effective manner [35,97]. In spinal surgery, NSAIDs induced inhibition of fusion is still under debate and discussed in another section.

Two meta-analyses of RCTs in spine surgery showed that preoperative use of gabapentinoids resulted in a reduction in total morphine consumption in the first 24–48 h, lower pain scores, and a significantly lower incidence of morphine related side effects such as postoperative nausea and vomiting (PONV), pruritus, and urinary retention compared to placebo. There was no significant difference in the occurrence of gabapentinoid related sedation or dizziness [98,99]. Dosing of acetaminophen, NSAIDs, and gabapentinoids should ideally be adjusted based on age, renal function, and other comorbidities.

Summary/recommendations:

The routine administration of sedatives to reduce anxiety preoperatively is not recommended

Quality of evidence: Low

Recommendation grade: Strong

The routine preoperative administration of acetaminophen, NSAIDs, and gabapentinoids as part of a multimodal opioid-sparing analgesia strategy is recommended.

Quality of evidence: Moderate

Recommendation grade: Strong

Anemia management

Preoperative anemia affects approximately one-third of patients undergoing elective surgery and is associated with an increased risk of transfusion, LOS, infection, morbidity, and readmission rate [100,101]. Evaluation of the National Surgical Quality Improvement Program database found that all levels of preoperative anemia were significantly associated with prolonged hospital LOS and poorer outcomes at 30-days in patients undergoing elective spine surgery [102]. Similarly, other studies have found preoperative anemia as an independent risk factor for perioperative complications [103–105]. Together, these studies suggest preoperative investigation for anemia is important, especially for patients undergoing major or complex spine surgery.

Interventions such as preoperative iron or erythropoietin therapy and postoperative re-transfusion of salvaged cells, in general, report a statistically significant and clinically relevant reduction in allogeneic blood transfusion [106–109]. Algorithm-led preoperative anemia screening in established ERAS centers performing spinal procedures has been associated with reduced blood transfusions, readmission, critical care admission, LOS, and cost [27].

In spine surgery, there is evidence to suggest that anemic patients undergoing complex spine surgery be administered oral iron supplementation, iron infusion, or erythropoietin to reach a target hemoglobin of 13 g/dL (130 g/L) [110]. However, this threshold is not widely accepted and has not been correlated to improved outcomes. If necessary, patients should be referred to hematology for further assessment and treatment. Future studies are required to determine the association of preoperative anemia optimization and perioperative outcomes in spine surgery [111,112].

Minimally invasive techniques could be recommended, as it has been shown that the blood loss is minimal with those procedures [28,112].

Summary/recommendations

Preoperative anemia should be assessed and corrected before lumbar fusion.

Quality of evidence: Low

Recommendation grade: Strong

Intraoperative recommendations

Antimicrobial prophylaxis and skin preparation

There is no universally accepted guideline for antibiotic/antiseptic prophylaxis for spinal fusion. One review in spinal surgery showed that preoperative screening and eradication of methicillin-sensitive or methicillin-resistant *Staphylococcus aureus* may reduce surgical site infections (SSI) in noncarriers compared to carriers [113]. Preoperative intranasal mupirocin ointment has also been shown to reduce SSI in orthopedic surgery significantly but has not been substantiated in spine surgery [114].

RCTs demonstrated that prophylactic antibiotics may be considered to decrease the rate of infection following instrumented spine fusion [115–117]. A more recent meta-analysis of RCTs cross-checks these data by showing a significant reduction in SSI after prophylactic antibiotic administration [118].

In synergy with this body of evidence, scientific societies have proposed guidelines for using perioperative prophylactic antibiotics in spine surgery [119,120]. Although the superiority of one antibiotic agent or dosing regimen over another has not been clearly demonstrated

[118,121], administration of a broad-spectrum antibiotic covering *S. aureus*, such as cefazolin, 30 minutes before skin incision with redosing every four hours during longer surgeries, has become common practice in spine surgery [122]. Each context needs to be evaluated, related to the patient's possible comorbidities and the complexity of the procedure [113].

The ideal skin intraoperative preparation to reduce the risk of SSI remains unclear in spine surgery. There was no clear benefit of chlorhexidine shower at home before surgical preparation [123], consistent with a Cochrane review on the same topic, which found no significant evidence to justify the use of preoperative cleansing as a strategy to prevent surgical site infections [124]. Antiseptic dressing the night before surgery was associated with a reduction in SSI after orthopedic surgery, but that has not been studied in spine surgery [125,126].

A meta-analysis of RCTs with various surgical procedures, including spine surgery, showed that alcohol-based agents are superior to aqueous solutions [127]. The use of either iodine preparation or chlorohexidine preparation provides adequate intraoperative skin preparation [128]. Chlorohexidine preparation could provide a more favorable longer-lasting effect for skin antisepsis in posterior spine surgery [127,129], but other RCTs demonstrated conflicting results, with conclusions favoring each preparation solution [130,131].

The timing of preoperative skin preparation is essential. One RCT using povidone-iodine demonstrated that bacteria on the skin are significantly reduced by allowing the preparation to dry for several minutes before spine surgery [132].

Summary/recommendation

A care bundle should be implemented, including administration of a broad-spectrum antibiotic covering S. aureus, and skin preparation using either alcohol-based iodine or chlorohexidine solution.

Administration of a broad-spectrum antibiotic covering Staphylococcus aureus (with possibility of repeating doses during longer surgeries)

Quality of evidence: High

Recommendation grade: Strong

Antiseptic dressing the night before surgery

Quality of evidence: Low

Recommendation grade: Moderate

Skin preparation using use of either alcohol-based iodine or chlorohexidine solution

Quality of evidence: High

Recommendation grade: Strong

Standard anesthetic protocol

The anesthetic protocol used in lumbar fusion surgery is varied with a few high-quality studies that have compared the efficacy of various methods. In a large observational study of spine surgery using propensity score analysis, there was no difference between nongeneral and general anesthesia for readmission rates, complications, and LOS [133]. An RCT including 80 spinal surgery patients showed significant improvement in hemodynamic stability, blood loss, and pain control with nongeneral anesthetic techniques [134]. Additionally, epidural anesthesia, combined with general anesthesia, also appears to limit blood loss [135].

There are many options for general anesthesia because of the wide range of available drugs and modes of delivery. Two RCTs reported that the use of neuromuscular blockade reduced airway pressure and muscle damage associated with prolonged retraction in spine surgery [136,137]. Inhaled anesthetics (e.g., sevoflurane) have been shown to improve the time to orientation in the post-anesthetic care unit and lower pain scores in the first 24 hours after surgery [138]. Furthermore, dexmedetomidine and ketamine have been shown to provide improved pain control, and dexmedetomidine alone is associated with a lower incidence of PONV in RCTs [139–141].

Summary/recommendation

Modern general anesthesia, including the use of neuromuscular blockade and neuraxial techniques should be used as part of multimodal anesthetic strategies follow local policy and availability.

Quality of evidence: Moderate

Recommendation grade: Strong

Preventing intraoperative hypothermia

Intraoperative hypothermia should be avoided as it has been associated with increased blood loss, cardiac complications, shivering, SSIs, and prolonged LOS [142–147]. Based on a large body of strong evidence, the UK's National Institute for Health and Care Excellence recommends prewarming of patients and active warming for all adults undergoing surgery throughout the intraoperative period [148].

Strategies to prevent hypothermia include the use of warmed infusion liquids, prewarming, and forced air-warming blankets and devices [149–156]. Ten minutes of prewarming could reduce hypothermia, and its adverse effects significantly [157]. Circulating warming garments offer better temperature control than forced-air warming systems, but both are more effective than passive warming devices [158–160].

Summary/recommendation

Normothermia should be maintained peri- and postoperatively through prewarming and active warming of patients intraoperatively.

Quality of evidence: High

Recommendation grade: Strong

Surgical techniques

There is a significant number of articles in the literature linking the notion of a particular spinal surgery technique to a reduction of the LOS, by optimizing the approach, reducing bleeding, controlling pain, etc. [12,161]. However, no single technique (approach, minimally or less invasive technique, endoscopy, specific implants, navigation, robotics, biologics, etc.) could be independently shown to accelerate the achievement of discharge criteria. No RCTs could be found in the literature combining ERAS and surgical techniques. Several recent retrospective studies involved the use of minimally invasive techniques [28–30] and had rationales close to that of the ERAS. In all studies, the surgical technique was not limited or dictated by the ERAS protocol. Due to the lack of unequivocal data, the selection of surgical technique for future ERAS protocols should factor in surgery goals, surgeon's experience, and the availability of equipment at the local institution [29,161–163].

Summary/recommendation

Surgical techniques should be decided on a case-by-case basis, factoring surgery goals, training, and experience of the surgeon, and the availability of technology at the local institution.

Quality of evidence: Low

Recommendation grade: Strong

Local, regional anesthetic techniques

The use of local, regional techniques for pain management is an attractive option for spinal surgery to improve postoperative pain control and the undesirable side effects of opioids that can delay recovery. A multimodal approach using local and regional anesthesia techniques, such as spinal or epidural analgesia, regional blocks, or wound infiltration, could reduce opioid consumption, side effects of these drugs, and improve analgesic efficacy.

Four RCTs evaluating intrathecal morphine injection compared to placebo have been shown to reduce pain scores and reduce postoperative systemic opioid use without significant adverse events [164–167]. However, the incidence of pruritus appears to be higher [167,168]. The addition of naloxone may facilitate the efficacy of intrathecal morphine injection and reduce complications (e.g., pruritus and nausea) [169]. Even for minimally invasive surgery, intrathecal morphine injection reduces postoperative pain and patient-controlled analgesia (PCA) morphine consumption [170]. Fentanyl is also efficacious for spinal analgesia [171].

Additionally, epidural analgesia (EA) is effective in reducing postoperative pain after lumbar fusion without significant side effects [172,173]. The use of a long-acting local anesthetic (ropivacaine, levobupivacaine, bupivacaine) or a combination of local anesthetic and opioid appears to be a better option than morphine alone to reduce postoperative pain as demonstrated in a series of RCTs in lumbar fusions patients [172–178]. Three other RCTs on major spinal surgery showed improved efficacy and patient satisfaction of EA compared with

PCA [174–176]. The best regimen (single shot, continuous infusion, patient-controlled epidural analgesia) of epidural analgesia is unresolved. Optimal results appear if epidural analgesia is started early in the procedure [179,180]. With a small dose of local anesthetic, the transient motor deficit is not described [172].

Regarding regional plane blocks, different techniques have been described in spinal surgery (erector spinae plane block, quadratus lumborum, thoraco-lumbar interfacial plane (TLIP) block). Only the TLIP block has been evaluated for lumbar fusion: in a randomized, double-blind placebo-controlled trial, the TLIP block significantly reduced analgesic drug consumption at 24 and 48 hours, pain, and length of stay without complications [181].

A prospective cohort study showed wound infiltration (WI) to effectively reduce postoperative pain after lumbar fusion [182], but well-designed RCTs are lacking. One randomized double-blinded placebo-controlled trial, including 120 patients with posterior lumbar spine surgery, evaluated wound infiltration with bupivacaine combined with local methylprednisolone vs. placebo and demonstrated significantly improved postoperative analgesic management (reduction in opioid utilization, lower pain scores, and higher patient satisfaction) [183]. Continuous infiltration using a wound catheter provides good pain relief for up to 48 h [182,184] and adding dexmedetomidine or clonidine (α2-agonists) to topical local anesthetics (bupivacaine or ropivacaine) increases the effectiveness of wound infiltration [185,186].

Summary/recommendation

Use of intrathecal morphine, epidural analgesia, locoregional blocks, or wound infiltration with long-acting local anesthetics should be used to improve postoperative pain management.

Intrathecal analgesia

Quality of evidence: High

Recommendation grade: Strong

Epidural analgesia

Quality of evidence: High

Recommendation grade: Strong

Locoregional blocks

Quality of evidence: High

Recommendation grade: Weak

Wound infiltration

Quality of evidence: High

Recommendation grade: Strong

Perioperative fluid management

Careful perioperative fluid management is key as hyper- or hypovolemia is associated with inadequate cellular oxygen delivery, particularly in patients with poor cardiovascular and renal reserve. Patients on ERAS pathways are generally in a state of euvolemia, due to several factors, such as reduced preoperative fasting time and carbohydrate loading. Goal-directed fluid management is often a recommended element in ERAS protocols [187]; however, there is limited evidence in its effectiveness in spine surgery [188–190]. One study showed that goal-directed fluid management resulted in the early return of bowel function after major spinal surgery [191]. Applied to scoliosis surgery, a similar protocol was associated with less crystalloid fluid administration, fewer perioperative transfusions, and significantly improved diuresis [192]. Other studies have shown excessive intravenous fluids to be associated with ileus [193,194]. One RCT in spine surgery evaluated the choice of fluid and concluded that normal saline made patients acidotic due to its high chlorine content [195]. A recent meta-analysis did not find the use of colloids nor different volumes of crystalloids administered to be associated with LOS after short construct lumbar fusion [196]. These findings are corroborated by other retrospective studies [197,198]. In common with ERAS protocols for other surgical disciplines, administering balanced intravenous solutions maintaining euvolemia is recommended.

Summary/recommendation

Intravenous fluids should be maintained near-euvolemic status.

Quality of evidence: Moderate

Recommendation grade: Strong

Goal-directed fluid management is not needed for 1–2 level lumbar fusion but should be considered if significant patient comorbidities exist.

Quality of evidence: Low

Recommendation grade: Strong

Early postoperative oral nutrition

No studies have investigated the direct association of early feeding or postoperative nutritional supplementation with ERAS in spine surgery [36]. However, return to normal food intake is considered an essential component of ERAS protocols to return to normal activities [1,36]. Most "fast-track" programs in orthopedic surgery promote early oral nutrition after surgery, but the mention of specific nutritional diets is highly variable or not detailed [199–201]. Early return to a normal diet is a principal component of orthopedics ERAS protocols, and patients should be encouraged to eat and drink as soon as they feel able. No study reported nutritional counseling or ad hoc diet to be continued after the discharge.

Summary/recommendation

An early return to a normal diet is recommended and should be promoted.

Quality of evidence: Low

Recommendation grade: Strong

Urinary drainage

Urinary catheterization is commonly placed intraoperatively, to monitor urine output, prevent bladder distention, and serve as a surrogate marker for hemodynamic stability [202]. However, prolonged urinary drainage is associated with complications such as urinary tract infections, surgical site infections, and postoperative urinary retention (POUR) following spine surgery [203,204]. Patients who develop POUR after spine surgery are at increased risk of sepsis and have increased LOS and cost to the healthcare system [205,206]. Limited urinary catheterization in patients undergoing spine surgery can potentially avoid or minimize adverse events and facilitate patient ambulation [111]. For example, one study reported the initial ERAS experience with minimally invasive lumbar interbody fusion procedures under local anesthesia where they managed without the use of urinary catheters [207].

The use of urinary catheters should be avoided in patients scheduled for short elective spinal operations and, if used, they should be removed within hours after surgery. Careful evaluation of postvoid volumes is necessary after spinal operations to ensure patients do not develop POUR [205].

Summary/recommendation

The routine use of urinary catheters is not recommended for short-segment elective lumbar spinal fusions with or without concomitant decompression. When used, they should be removed within hours of surgery with close monitoring.

Quality of evidence: Moderate

Recommendation grade: Weak

Postoperative recommendations

Postoperative analgesia

Poor postoperative pain control is observed in 57% of patients following elective spine surgery [208]. Inadequate acute pain control is associated with the development of chronic pain and significant systemic inflammatory response leading to organ dysfunction and pain [209,210]. A standardized perioperative multimodal antinociceptive protocol results in adequate postoperative pain relief and improved outcomes [5]. Acetaminophen (paracetamol) is a basic part of perioperative multimodal pain management and is used widely, either orally or intravenously [35,211]. Acetaminophen is an analgesic and antipyretic but is not anti-inflammatory, and its analgesic activity is additive to other analgesic drugs like NSAIDs and opioids [35,211,212]. Despite its hepatic toxicity, acetaminophen is likely one of the safest and most cost-effective nonopioid analgesic drugs [211].

RCTs and meta-analysis of RCTs focusing on spine showed that NSAIDs, including selective COX-2 inhibitors, are highly effective in reducing pain and key in opioid-sparing strategies in multimodal analgesia [212–216]. COX-2 drugs that do not affect platelet aggregation can be prescribed if surgeons are concerned about bleeding [35,212–216].

There is still debate about whether NSAIDs are associated with an increased incidence of impaired osteogenesis and pseudarthrosis after spinal fusion. However, there is no conclusive evidence for the negative impact of NSAIDs on bone healing, and there is evidence that short-term (<2 weeks) perioperative NSAID use does not influence fusion rates [217,218]. Therefore, acetaminophen and NSAIDs, including COX-2 inhibitors, should be part of a multimodal strategy after spinal surgery unless there are patient specific contraindications for its use."[218].

Opioids are effective in treating acute postoperative pain following spinal surgery [210]. However, opioid-sparing techniques are important and should be applied in ERAS pathways to allow patients to recover early and reduce complications related to opioid use [210].

Several RCTs in other surgical specialties investigated multimodal opioid-sparing techniques for postoperative analgesia, including acetaminophen, NSAID's, gabapentin, α2-agonists, S-ketamine, magnesium sulfate, high-dose steroids, and local anesthetic infusion (epidural or intravenous) or patient-controlled analgesia with morphine, which showed a decrease in pain reduction [35,210,211,219–221]. However, well-designed studies with the highest level of evidence in spinal surgery are inconclusive or lacking.

Summary/recommendation

The routine use of multimodal analgesic regimens to improve pain control and reduce opioid consumption is recommended.

Quality of evidence: Moderate

Recommendation grade: Strong

Postoperative nausea and vomiting

PONV is essential for patients undergoing any type of surgery. PONV results in mild to severe dehydration, delayed return of adequate nutrition intake, increased intravenous fluid administration postoperatively, prolonged LOS, and increased healthcare costs [222,223]. Furthermore, PONV affects 30–50% of all surgical patients, and up to 80% of patients are at high risk for developing PONV [222,223]. Therefore, preoperative risk assessment is essential in ERAS pathways and should also be applied in spine surgery [224]. Major risk factors are female gender, patients with a history of PONV or motion sickness, and non-smokers [225,226].

The use of volatile anesthetic gases, nitrous oxide, and opioids increases the risk of PONV significantly [227]. Several scoring systems have been developed for the prediction of PONV, and the most used are the Koivuranta score and Apfel's simplification of this score. These scores are useful when combined with specific therapeutic interventions, especially in high-risk patients [223].

There are several classes of first-line antiemetic drugs, including dopamine (D2) antagonists (e.g., droperidol), serotonin (5HT3) antagonists (e.g., ondansetron), and corticosteroids (e.g., dexamethasone). If rescue PONV treatment is required, a different class of antiemetics should be administered than the one administered for prophylaxis [223,228,229]. Second-line drugs may also be used, such as antihistamines (e.g., promethazine), anticholinergics (e.g., scopolamine), and other D2 antagonists, such as metoclopramide, but their use may be limited by common side effects such as sedation, dry mouth, blurred vision, and dyskinesia [228].

Summary/recommendation

Risk assessment for PONV, routine use of multimodal PONV prophylaxis based on assessment and PONV rescue with a different class of anti-emetic, is recommended.

Quality of evidence: High

Recommendation grade: Strong

Postoperative management of drains

Forty-seven studies concerning postoperative drainage were relevant to ERAS protocols for lumbar fusion. A summary of the findings was that sub-fascial drain usage in fusion surgery to treat lumbar degenerative disease is common, but the literature on its utility is of low quality (case series, uncontrolled cohort studies, review of level 3 evidence). The common practice of using drains stems from its relatively low cost and morbidity [230]. The primary utility identified was for the reduction in SSI and postoperative epidural hematoma (PEH) formation, complications carrying significant clinical consequences [231].

Four RCTs indicate that drain placement was not shown to result in lower incidence of either SSI or PEH [232–235]. While not all the relevant studies were focused on lumbar fusion, numerous large cohort studies [236–239] and literature reviews [240,241] have demonstrated similar findings. Of note, a Cochrane Review of orthopedic procedures in general (including spine) drew similar conclusions [242]. In addition, prolonged drainage was associated with higher SSI rates, although it was unclear whether this was predictive or causative [243,244]. Nonfusion studies have suggested that the evacuation of hematoma at the surgical site via drainage may reduce the rate of delayed epidural fibrosis from blood collections [234]. However, for short-segment and less invasive fusion surgeries, the use of a drain delayed ambulation and was associated with more pain at the surgical site, and thus has implications for ERAS protocols [244].

Summary/recommendation

Routine wound drainage is not recommended for short-segment lumbar fusion surgery.

Quality of evidence: Moderate

Recommendation grade: Strong

Prophylaxis against thromboembolism

The estimated incidence of symptomatic deep vein thrombosis and pulmonary embolism following elective spinal surgery is low at 0.9% (range: 0–3.5%) and 0.7% (range: 0–7.6%), respectively [245]. The low incidence of venous thromboembolism (VTE), including patients with no prophylaxis, and the lack of evidence regarding the optimal choice for thromboprophylaxis after spinal surgery have led to wide variations in practice [246,247]. The few RCTs in the literature on this topic have a relatively small sample size [248–250]. Other studies are not randomized [251,252], which is particularly detrimental when attempting to detect infrequent outcomes such as VTE following elective spinal surgery.

However, early ambulation should be encouraged in all patients [246,247]. Given the relatively low cost, low complication rates, and documented efficacy, mechanoprophylaxis, such as compression stockings and intermittent pneumatic compression devices, should be considered in all patients following spinal surgery [251,253]. The use of chemoprophylaxis is more controversial. Some retrospective studies show that chemoprophylaxis is effective in reducing VTE [254–257], while other studies show no benefit [245,258,259]. One meta-analysis, based on 28 studies, showed that elective spinal surgery is associated with a low risk of VTE [245]. In this context, chemoprophylaxis may not be warranted, given the definable risk of postoperative epidural hematoma formation and other complications [254,259]. Chemoprophylaxis may be more appropriately used in high-risk patients, such as those with advanced age, neurological deficits, history of VTEs, and those undergoing surgery for spinal deformity, trauma, and metastatic bone disease [260–266]. There is insufficient evidence to recommend the timing of initiation and the duration of thromboprophylaxis [267].

Summary/recommendation

Early ambulation and the use of mechanoprophylaxis should be encouraged in all patients after spinal surgery.

Quality of evidence: Moderate

Recommendation grade: Strong

Pharmaceutical antithrombotic prophylaxis should be reserved for specific risk groups, while no recommendation can be made concerning standardized use.

Quality of evidence: Low

Recommendation grade: Strong

Early mobilization and in-hospital physical therapy

Patients should be encouraged to mobilize as soon as they are able, to counteract the adverse physiological effects associated with prolonged bed rest (such as insulin resistance, muscle atrophy, reduced pulmonary function, impaired tissue oxygenation, and increased risk of thromboembolism) [268]. There is an absence of level 1 publications specifically examining the role of early mobilization in spine surgery. However, in numerous cohort studies, early mobilization following spinal surgery and other major procedures has been linked to reduced morbidity and LOS [269]. Goal-directed early mobilization has been recommended following spinal surgery [270], with LOS reduced for lumbar fusion patients ambulating at least 30 feet / 10 meters on the day of surgery [271].

Furthermore, early commencement of physical therapy in spine surgery patients has been shown to facilitate early return to functional activity in RCT [272]. Patients with chronic back pain who undergo lumbar spinal fusion surgery often have high levels of kinesiophobia and can have prolonged inactivity postoperatively [273]. Early involvement of physical therapists in high-risk patients may increase postoperative mobilization and prevent the negative effects of prolonged bed rest. Before discharge, independent transfer and stair climbing should be achieved [274].

Summary/recommendation

Early mobilization and early physical therapy are recommended.

Quality of evidence: Low

Recommendation grade: Strong

Continuous improvement and audit

The previous implementation of ERAS protocols in other surgical disciplines has led to a reduction in complications, shorter LOS, and improved cost savings, demonstrating a good example of value-based healthcare [275,276]. The analysis of the literature on ERAS audit is based almost exclusively on systematic reviews, and prospective studies on this topic are still to be developed. However, one prospective analysis comparing self-declared ERAS with non-ERAS hospitals demonstrated that having an ERAS protocol is not enough to improve patient outcomes [277]. Daily practice is influenced by opinions and memories. Evidence-based medicine improves personal performance and raises the overall standard of health care delivery [278]. The implementation of enhanced recovery pathways is successful in hospitals with data feedback of process and outcome measures [279]. Staff are positive about the implementation of ERAS but find the process difficult [280]. Monitoring, feedback of processes, and outcome measures are essential to secure a successful implementation of ERAS guidelines [279]. It is also helpful for health professionals to maintain high compliance with ERAS recommendations and quality improvement [5,29,275,281]. Multidisciplinary teams are recommended to implement ERAS protocols [280,282]. Patients appear to be more satisfied and motivated in ERAS programs [283–285].

Summary/recommendation

Routine auditing and feedback are necessary for implementing ERAS protocols, maintaining high compliance with ERAS protocols, and realizing quality improvements.

Quality of evidence: Low

Recommendation grade: Strong

Summary and Conclusion

This consensus statement represents the most recent evidence-based recommendations from the ERAS® Society Guideline group for the perioperative management of patients undergoing lumbar fusion for degenerative spinal conditions (Figure 1). A detailed summary of the recommendations is provided in Table 3.

These guidelines are important in summarizing the large volume of heterogeneous studies across all ERAS items for lumbar fusion, a surgical area where the application of ERAS is still in its infancy. The authors' recommendations provided in this guideline are following the methods set out by the ERAS® Society and based on the synthesis of objective assessment of the best available evidence in lumbar fusion surgery, other surgical disciplines, and expert opinion of the guideline development group. As such, strong recommendations may be reached from low-quality or conflicting data and vice versa. Likewise, this methodology explains that certain levels of evidence have been downgraded if extrapolated from other surgical areas.

The main purpose was to define current standards to enable new multidisciplinary teams to implement these procedures in their practice to improve outcomes. This consensus statement also highlights the numerous research opportunities that exist and encourages further research in areas where procedure-specific research is required. Indeed, while the few clinical studies available seem promising, studies of high methodological quality are needed.

The lines of research to be developed could include prehabilitation measures, pain control in this highly painful surgery, improvement of psychological evaluation in this functional area, improvement of the evaluation of surgical techniques, standardized postoperative rehabilitation recommendations, the possible introduction of outpatient management, and integration of patient related outcomes (PROs) in the permanent evaluation of results.

This work also confirms that the successful implementation of ERAS protocols for spine surgery is an inherently multidisciplinary concept, and in fact, surgical techniques do not matter in the overall management, as has already been seen in other disciplines.

Techniques such as minimally invasive techniques have elements very close to the ERAS concepts (e.g., decrease surgical stress). However, there is no evidence to recommend them over traditional open procedures.

It is essential to promote the evaluation of the implemented procedures, permanent audits of the teams, analysis of the results, including PROs, and compliance with the proposed ERAS protocols, including regular updates.

Spine surgery includes multiple areas of development, and we emphasize that our recommendations are addressed to lumbar fusion, frequently defined by short constructs and relatively fast operating times. Many opportunities will open up in the future for ERAS recommendations for other spinal procedures, cervical spine surgery, anterior or combined approaches, complex deformities and scoliosis, etc.

As in other areas of surgery, a successful introduction of ERAS protocols for lumbar fusion is possible, but a broad-based, multidisciplinary approach and system support is imperative for success.

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Figure Caption

Figure 1. Summary of recommended perioperative topics for ERAS and lumbar fusion

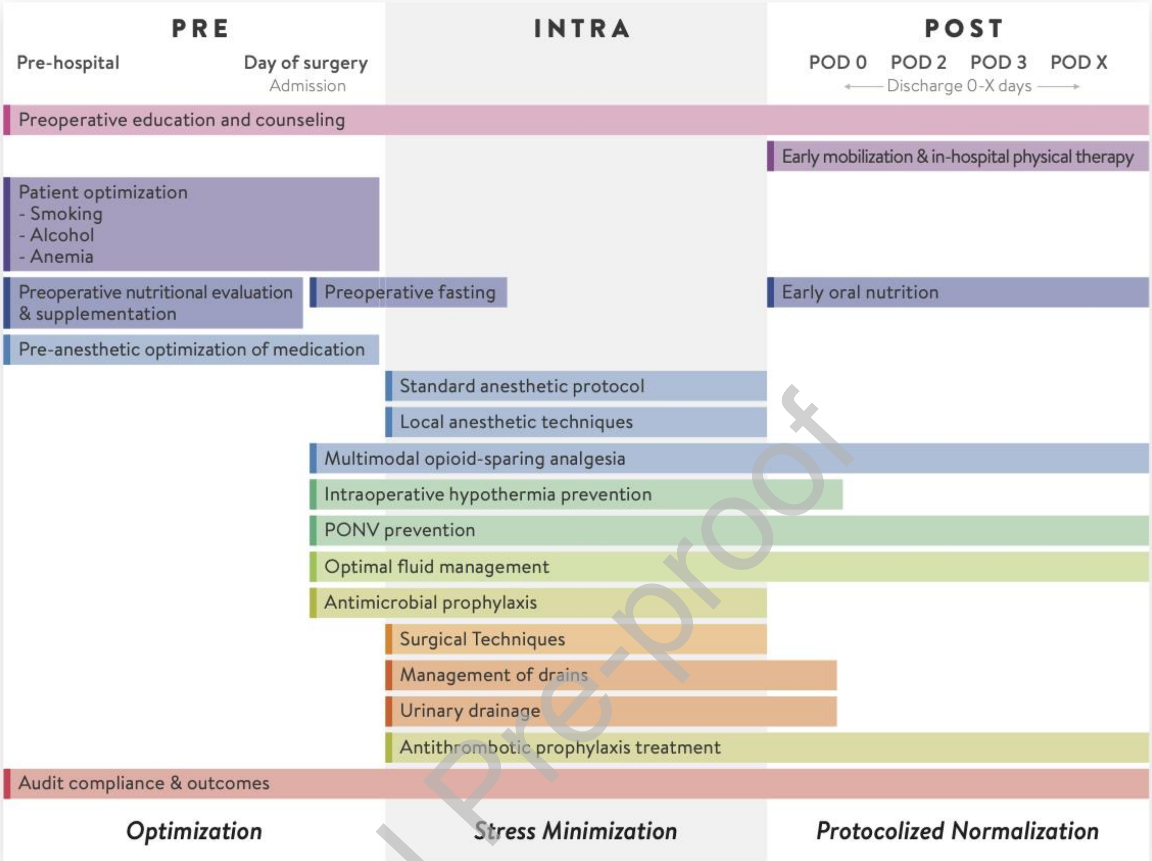

Table 1
GRADE system for rating quality of evidence [31]

Evidence level	Definition
High quality	Further research unlikely to change confidence in estimate of effect
Moderate quality	Further research likely to have important impact on confidence in estimate of effect and may change the estimate
Low quality	Further research very likely to have important impact on confidence in estimate of effect and likely to change the estimate
Very low quality	Any estimate of effect is very uncertain

GRADE, Grading of Recommendations, Assessment, Development and Evaluation

Table 2
GRADE system for rating strength of recommendations [31]

Recommendation Strength	Definition
Strong	When desirable effects of intervention clearly outweigh the undesirable effects, or clearly do not
Weak	When trade-offs are less certain—either because of low-quality evidence or because evidence suggests desirable and undesirable effects are closely balanced

GRADE, Grading of Recommendations, Assessment, Development and Evaluation

Table 3
Summary of recommended interventions for the perioperative care of lumbar fusion

Nb	Item	Recommendation	Evidence Level	Recommendation Grade
Pre-Operative Recommendations				
1	Preoperative education & counselling	Preoperative patient education is recommended.	Low	Strong
2	Prehabilitation	Evidence is currently insufficient to make a recommendation on prehabilitation as an essential intervention for all patients.		
3	Preoperative nutritional supplementation	Patients undergoing lumbar fusion should undergo a preoperative nutritional assessment.	Low	Strong
		Preoperative nutritional interventions should be offered to patients identified as malnourished	Low	Strong
4	Preoperative cessation of smoking	A combined smoking cessation therapy at a minimum of 4 weeks before surgery is recommended.	Moderate	Strong
5	Preoperative cessation of alcohol	Alcohol cessation programs 4-8 weeks before surgery can reduce postoperative complications.	Moderate	Strong
6	Preoperative fasting and carbohydrate treatment	Clear fluid should be permitted up to 2h and solid foods up to 6h before the induction of general anesthesia.	High	Strong
		Evidence is currently insufficient to make a recommendation on routine use of oral carbohydrate load for lumbar spine fusion.		
7	Pre-anesthetic medication	The routine administration of sedatives to reduce anxiety preoperatively is not recommended	Low	Strong
		The routine preoperative administration of acetaminophen, NSAIDs, and gabapentinoids as part of a multimodal opioid sparing analgesia strategy is recommended.	Moderate	Strong
8	Anemia management	Preoperative anemia should be assessed and corrected prior to lumbar fusion.	Low	Strong
Intra-Operative Recommendations				
9	Antimicrobial prophylaxis and skin	A care bundle should be implemented, including administration of a broad-spectrum antibiotic		

	preparation	covering S. aureus, and skin preparation using either alcohol-based iodine or chlorohexidine solution.		
		Administration of a broad-spectrum antibiotic covering S. aureus (with possibility of repeating doses during longer surgeries)	High	Strong
		Antiseptic dressing the night before surgery	Low	Moderate
		Skin preparation using use of either alcohol-based iodine or chlorohexidine solution	High	Strong
10	Standard anesthetic protocol	Modern general anesthesia, including the use of neuromuscular blockade and neuraxial techniques should be used as part of multimodal anesthetic strategies follow local policy and availability.	Moderate	Strong
11	Preventing intraoperative hypothermia	Normothermia should be maintained peri- and postoperatively through pre-warming and the active warming of patients intraoperatively	High	Strong
12	Surgical techniques	Surgical technique should be decided on a case-by-case basis factoring the goals of surgery, training and experience of the surgeon, and the availability of technology at the local institution.	Low	Strong
13	Local anesthetic techniques	Use of intrathecal morphine, epidural analgesia, locoregional blocks or wound infiltration with long-acting local anesthetics should be used to improve postoperative pain management.		
		Intrathecal analgesia	High	Strong
		Epidural analgesia	High	Strong
		Locoregional blocks	High	Weak
		Wound infiltration	High	Strong
14	Perioperative fluid management	Intravenous fluids should maintain near-euvolemic status.	Moderate	Strong
		Goal directed fluid management is not needed for 1-2 level lumbar fusion but should be considered if significant patient co-morbidities exist.	Low	Strong
15	Early postoperative oral nutrition	An early return to normal diet is recommended and should be promoted.	Low	Strong
16	Urinary drainage	The routine use of urinary catheters is not recommended for short-segment elective lumbar spinal fusions with or without concomitant decompression. When used, they should be removed within hours of surgery with close monitoring	Moderate	Weak

Post-Operative Recommendations				
17	Postoperative analgesia	The routine use of multimodal analgesic regimens to improve pain control and reduce opioid consumption is recommended.	Moderate	Strong
18	Postoperative nausea and vomiting	Risk assessment for PONV, routinely use of multimodal PONV prophylaxis based on assessment, and PONV rescue with different class of anti-emetic are recommended	High	Strong
19	Postoperative management of drains	Routine wound drainage is not recommended for short-segment lumbar fusion surgery	Moderate	Strong
20	Prophylaxis against thromboembolism	Early ambulation and the use of mechano-prophylaxis should be encouraged in all patients after spinal surgery.	Moderate	Strong
		Pharmaceutical antithrombotic prophylaxis should be reserved for specific risk groups, while no recommendation can be made with regard to its standardized use.	Low	Strong
21	Early mobilization and in-hospital physical therapy	Early mobilization and early physical therapy are recommended	Low	Strong
22	Continuous improvement and audit	Routinely auditing and feedback is necessary for implementation of ERAS protocols, maintaining high compliance to ERAS protocols and realizing quality improvements	Low	Strong