Development and implementation of a comprehensive spine surgery enhanced recovery after surgery protocol: the Cleveland Clinic experience

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Enhanced recovery after surgery (ERAS) protocols have been shown to be effective at reducing perioperative morbidity and costs while improving outcomes. To date, spine surgery protocols have been limited in scope, focusing only on specific types of procedures or specific parts of the surgical episode. The authors describe the creation and implementation of one of the first comprehensive ERAS protocols for spine surgery. The protocol is unique in that it has a comprehensive perioperative paradigm encompassing the entire surgical period that is tailored based on the complexity of each individual spine patient.

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THE current healthcare climate focuses on evidence-based medicine that is efficient, safe, and cost-effective. Therefore, many surgical centers place greater emphasis on standardized protocols designed to maximize patient outcomes among all surgical specialties. Between 2004 and 2015, the number of elective lumbar fusions increased by 62.3% and was especially high among patients older than 65 years (138.7%). Overall hospital costs also increased by 177% during this period, exceeding \$10 billion in 2015.⁴⁰ Enhanced recovery after surgery (ERAS) protocols utilize an iterative approach based on the best available medical evidence at each step of the surgical episode. At the Cleveland Clinic Foundation (CCF), we implemented a unique, comprehensive, multidisciplinary approach to optimize outcomes in all spine surgery cases performed at the main campus. The protocol is unique in that it has a comprehensive perioperative paradigm encompassing the entire surgical period that is tailored based on the complexity of each individual spine surgery.

Preliminary evidence from various surgical specialties, including general surgery and neurosurgery, has demon-

strated that the ERAS approach improves patient outcomes, including decreased hospital length of stay (LOS) and postoperative complications.³⁸ Liu et al. described a large-scale ERAS program within Kaiser Permanente Northern California that included 17,000 patients undergoing colorectal and hip surgery across 20 medical centers. This program consisted of 5 operational elements: preoperative surgical preparation; intraoperative normovolemia; multimodal pain management through the preoperative, perioperative, and postoperative phases of care; early feeding and nutrition after surgery; and postoperative mobilization. Compared with contemporaneous surgical groups prior to implementation of their ERAS program, they found significant improvement in the areas of ambulation, nutrition, and opioid use. Hospital LOS and postoperative complication rates were also significantly lower.³⁷

At CCF, a comprehensive protocol was designed and implemented to mitigate risks regarding preoperative, intraoperative, and postoperative care and improve outcomes. The protocol identifies the most relevant factors that have been correlated with adverse outcomes and in-

ABBREVIATIONS CCF = Cleveland Clinic Foundation; DVT = deep venous thrombosis; ERAS = enhanced recovery after surgery; LOS = length of stay; NSQIP = National Surgical Quality Improvement Program; POD = postoperative day; SSI = surgical site infection; TXA = tranexamic acid; VTE = venous thromboembolism.

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FIG. 1. ERAS protocol at CCF.

creased rates of postoperative complications and utilizes an evidence-based strategy to address those factors (Fig. 1). The protocol was completely implemented by October 2017. Additional refinement was based on the expertise of subspecialists from the CCF Center for Spine Health and the anesthesiology, endocrinology, geriatrics, blood management, and bariatric departments.

The CCF ERAS Protocol

The primary goal of the CCF ERAS program is to improve patient clinical outcomes, reduce hospital LOS, reduce postoperative narcotics use, and decrease the need for blood transfusions. Previous studies have shown that independently controlling for these risk factors improved outcomes after spine surgery.^{19,44,45} We identified 3 phases in which the CCF protocol aims to optimize patient care in spine surgery: preoperative risk assessment and mitigation, individualized perioperative care, and postoperative recovery and mobilization. In the first phase, preoperative risk assessment and mitigation, the spine surgery patient's comorbidities are identified, and interventions are initiated in an effort to medically optimize the disease status well before the intended surgical date (Fig. 2). The second phase, individualized perioperative care, begins on the day of surgery and continues through the operation itself. Perioperative pain management, fluid resuscitation, and blood management plans are discussed and finalized with the anesthesia team. The third phase, postoperative recovery and mobilization, emphasizes early mobilization with the introduction of physical and occupational therapy as needed, deep venous thrombosis (DVT) prophylaxis, and multimodal postoperative pain management. Each phase of the CCF ERAS protocol receives direct input from re-

spective subspecialists to optimize these modifiable risk factors before, during, and after spine surgery.

Preoperative Risk Assessment and Mitigation Risk Stratification

The field of spine surgery encompasses a wide variety of surgical procedures from short, almost bloodless outpatient procedures to extremely long reconstructive procedures requiring multiple transfusions. In order to more accurately assess and provide the optimal care to each patient, spine surgeries were divided into 3 categories: minor, major, and complex surgeries. Minor surgeries are those that have a predicted blood loss of less than 100 ml. Examples of cases in this category include microdiscectomies, cervical discectomies, and vertebral augmentation. Major spine surgeries have a predicted blood loss between 100 ml and 1000 ml. The majority of elective spine surgeries for degenerative disease fall into this category. Complex cases are those that have a potential blood loss of greater than 1 L (Table 1). Decisions about appropriate preoperative testing and anesthesia plans are based on this risk stratification, along with each individual patient's medical history.

Tobacco Use

During the preoperative clinic appointments, patients are screened for tobacco use. Active smokers are actively counseled on the benefits of quitting or decreasing tobacco consumption. Smoking cessation therapies such as nicotine patches are advised, and the surgeon informs the patient of his or her options. Jackson and Devine, in their systematic review of the literature, concluded that current

FIG. 2. Preoperative benchmarks for ERAS. EPO = erythropoietin; Hgb = hemoglobin; Pt = patient.

smokers have a significantly higher pseudarthrosis and postoperative infection rate.²⁸ Chiang et al. studied 848 nonsmokers, current smokers, and former smokers. They found that male current smokers required more opioid analgesia during the first 72 hours after surgery than the other 2 groups.⁹ In addition, they also reported higher pain intensity scores on postoperative day (POD) 1. Patients undergoing elective fusion surgery are required to cease nicotine use prior to scheduling surgery. Nicotine levels are obtained prior to surgery to ensure compliance with the cessation requirement.

Obesity

Patients with a BMI greater than 40 are not considered for elective spine surgery and are referred to the bariatric clinic at CCF. Patients work with bariatric specialists to improve their nutritional status, lose weight, and optimize them for spine surgery. If they are able to lower their BMI, then elective spine surgery will be considered. Obesity increases the risk of postoperative surgical site infection (SSI) and venous thromboembolism (VTE).²⁷ Marquez-Lara et al. reported a significantly higher rate of VTE in individuals with a BMI greater than 25 in their review

of the National Surgical Quality Improvement Program (NSQIP) database (24,196 patients).³⁹

Diabetes

In known diabetics or patients with a BMI ≥ 35 , an HbA1c (hemoglobin A1c) is documented. Patients with HbA1c $> 8\%$ are referred to the endocrinology clinic for preoperative optimization. Preoperatively, patients are encouraged to achieve an average blood glucose of less than 180 mg/dl (change in HbA1c does not show for an average of 3 months). Surgery is scheduled no earlier than 2 weeks after the initial endocrinology consultation to allow for adequate time for effective blood glucose management. Uncontrolled diabetes is a known risk factor of prolonged hospital LOS and postoperative complications. Gustafsson et al. found that a high preoperative HbA1c is predictive of adverse outcomes.²² Van den Boom et al. described goal variables to achieve prior to surgery.⁵¹ Epstein reviewed a cohort from the Nationwide Inpatient Sample of 197,461 lumbar fusions between 1988 and 2003.¹³ The author found that diabetes was associated with higher rates of infection, transfusion, pneumonia, and in-hospital mortality; greater costs; and greater LOS. Cardiac literature has

TABLE 1. Classification scheme for spine surgery

Minor (EBL <100 ml)	Major (EBL 100–1000 ml)	Complex (EBL >1 L)
ACDF/PCDF	<3-level ALIF/TLIF/XLIF	Pedicle subtraction osteotomy
Decompression or microdiscectomy w/o fusion ≤2 levels	≤2 anterior/posterior fusion	Tumor corpectomy/debulking
		≥3 levels anterior/posterior fusion/instrumentation

ACDF = anterior cervical discectomy and fusion; ALIF = anterior lumbar interbody fusion; EBL = estimated blood loss; PCDF = posterior cervical discectomy and fusion; TLIF = transforaminal lumbar interbody fusion; XLIF = extreme lateral interbody fusion.

This classification scheme is utilized to subdivide cases and guide preoperative optimization (e.g., only major and complex cases are placed in the blood management pathway), intraoperative blood management, goal-directed fluid therapy, and other anesthetic benchmarks.

shown that maintaining blood glucose between 110 and 180 mg/dl in the perioperative period is ideal for superior outcomes in surgery.¹⁸ It has been well characterized in the spine literature that diabetic patients have a higher risk of postoperative infections. For example, Cancienne et al. demonstrated higher rates of infections for diabetics with an HbA1c above 7.5 in patients undergoing single lumbar decompression.⁵ The CCF ERAS protocol attempts to mitigate this risk factor by optimizing glycemic control before surgery under the evaluation and guidance of endocrinologists.

Age/Frailty

All patients undergoing elective spine surgery who are 75 years or older are referred to the geriatric medicine clinic for a frailty assessment. This clinic evaluates deconditioning, sarcopenia/malnutrition, dementia, and polypharmacy. A plan is implemented to optimize prehabilitation, nutritional supplementation, medication changes, and postoperative pain control to minimize delirium. Surgery is scheduled for no earlier than 6 weeks after the geriatrics consult to allow time for adequate optimization and prehabilitation when needed. Leven et al. evaluated 1001 patients to elucidate the relationship between frailty and outcomes in adult spinal deformity surgery.³⁴ They found that frailty was an independent predictor of postoperative complications, mortality, and reoperations. Flexman et al., in their review of patients undergoing surgery for degenerative spine disease, concurred.¹⁷ With a growing elderly population, the assessment of frailty in the decision-making process of spinal surgery is imperative. A high frailty index has been correlated with an increased risk of complications and an increased hospital LOS postoperatively.

Anemia/Blood Management

All patients undergoing either major or complex elective spine surgery are screened for anemia. Patients with hemoglobin ≤ 11.5 are referred to the blood management clinic. Patients are administered oral iron, an iron infusion, or erythropoietin to reach a target hemoglobin of 13 g/dl. If necessary, the patient is referred to hematology for further assessment. Seicean et al. evaluated the NSQIP database and found that all levels of anemia were significantly associated with prolonged hospital LOS and poorer outcomes at 30 days in patients undergoing elective spine surgery.⁴⁸ High preoperative anemia rates have been demonstrated to be an independent risk factor for increased LOS and perioperative complications such as thromboembolic events (Fig. 3).^{16,21}

Infection Prevention

A major source of morbidity after spine surgery is postoperative wound infection. As previously published, a bundled infection prevention protocol for elective spine surgery was implemented.¹⁵ This protocol included nasal swabs to assess for *Staphylococcus* colonization and a decolonization when appropriate, preoperative Hibiclens showers and wipes, and a standardized preoperative antibiotic protocol.

FIG. 3. Principles of intraoperative blood and fluid management.

Individualized Perioperative Care

Multimodal Pain Management

The use of opioids remains a significant problem in the United States. Many postoperative pain management protocols can be perceived as facilitators of the opioid epidemic due to the over-prescription of narcotic medications. The morning of surgery, all patients are given oral acetaminophen 1000 mg and gabapentin 300–650 mg. Acetaminophen and gabapentin have been shown to reduce the need for narcotics postoperatively.^{3,30} The combination of acetaminophen and gabapentin is more effective than either drug alone.^{29,42} This concept of protective premedication was introduced to protect the central nervous system from the harmful effects of noxious stimuli to the patient, resulting in hyperalgesia and allodynia. Syal et al. studied the combination of acetaminophen and gabapentin versus either agent alone given the morning of surgery.⁵⁰ Patients who consumed the combination regimen had lower visual analog scale scores at all time intervals postoperatively. In addition, this was found to extend the time to opioid rescue following lower-extremity surgery. The American Society of Anesthesiologists practice guidelines for acute pain management in the perioperative setting recommend the use of scheduled acetaminophen if there are no contraindications.²

The intraoperative analgesic protocol involves the use of nonsteroidal antiinflammatory drugs, ketamine, long-acting narcotic infusion, lidocaine, epidural pain catheters, and local wound infiltration with long-acting analgesic solutions. The surgeon and anesthesiologist discuss the timing and dose of these medications, taking into account previous doses consumed as an outpatient, goals of the surgery, and postoperative care needs.

The use of COX-2 inhibitors during the perioperative period has been reported to be effective in decreasing pain scores and opioid consumption postoperatively. Ketorolac is used almost universally at CCF. All patients are given intravenous ketorolac 15–30 mg unless contraindicated. Adding 30 mg intravenous ketorolac has been shown to decrease postoperative “rescue” morphine administration.⁷ It has long been believed that ketorolac can inhibit spinal fusion; however, recent literature has suggested that, if ketorolac dosing is limited to < 2 days and/or at doses of < 120 mg/day, the effect on spinal fusion rates is insignificant.^{35,36}

A ketamine infusion is utilized as an adjunctive anesthetic agent during and after the surgery. It has an opioid-sparing, dissociative effect and is advantageous in surgical patients in whom high postoperative opioid consumption is anticipated. Laskowski et al., in their systematic review, supported the benefit of ketamine when used in painful procedures, including abdominal, thoracic, and major orthopedic surgeries.³² This finding was independent of both the administration time and dose. The clinical effects of lidocaine exceed the duration of infusion by over

8 hours via an attenuation of portions of the proinflammatory system.¹² In major spine surgery, a lidocaine infusion has been shown to decrease postoperative pain and opioid consumption and improve functional outcome. Farag et al. demonstrated statistically significant greater SF-12 physical composite scores than placebo at 1 and 3 months postoperatively.¹⁴

Narcotics use is further limited by infusion of long-acting anesthetic medications via an epidural catheter. It can infuse medication for 2–3 days. Placement of an epidural patient-controlled anesthesia device has been shown to be more effective than intravenous patient-controlled anesthesia in spine surgery.^{46,52} Preincisional and postincisional wound infiltration with a local anesthetic is also performed. Long-acting agents (Marcaine, liposomal bupivacaine) are utilized at the end of cases. A single dose of liposomal bupivacaine has been associated with pain relief for up to 72 hours and reduction in total opioid consumption. Combination administration of both epidural analgesia and a local anesthetic resulted in improved pain scores (Fig. 4).

FIG. 4. Components of perioperative pain management.

Perioperative Fluid Resuscitation and Blood Management

Several meta-analyses and quantitative reviews have demonstrated improved perioperative outcomes when utilizing goal-directed fluid management.⁴ Perioperative morbidity is connected to the amount of intravenous fluid administered with both insufficient and excess fluid delivery, leading to increased postoperative complications.^{11,23,26,33} Pulse pressure variation is used as a guide to direct fluid boluses. An increase in pulse pressure variation greater than 13% is felt to be indicative of suboptimal stroke volume and the potential need for volume resuscitation. Much of the literature has demonstrated improved outcomes with boluses of colloids. We recommend giving maintenance-balanced crystalloid of 2–3 ml/kg/hr with additional boluses of fluid as needed, with colloids being preferred to minimize edema.

Intraoperative blood management consists of the use of tranexamic acid (TXA), standardized transfusion parameters, and the use of adjunctive devices to minimize blood loss. TXA has been shown to reduce total blood loss and the need for blood transfusion. All patients undergoing major and complex spine surgery receive a bolus of TXA and an additional infusion during the case. The optimal dose has not been established for surgery; however, 1 g is considered adequate, with higher doses showing no additional benefit.⁸ The use of cell salvage ensures that there is maximal efficiency of the return of blood products as required by each individual patient. There is also a specific intraoperative blood transfusion protocol directed by the anesthesia team. If the arterial blood gas demonstrates a hemoglobin level < 8 g/dl, or if there is ongoing blood loss, blood is transfused as guided by the staff anesthesiologist.

With the use of TXA and cell saver, the goal is to reduce the rate of intraoperative and postoperative transfusion. Increased rates of transfusion are associated with increased postoperative risk of morbidity. Glance et al. showed correlations between transfusion and pulmonary, septic, wound, and thromboembolic complications in patients undergoing noncardiac surgery when compared with non-transfused patients.²⁰ Studies have shown that transfusion is associated with increased risks of mortality and postoperative complications in cardiac surgery.^{31,41,49} Our aim was to target patients and procedures at high risk for blood transfusion to intervene pre- and intraoperatively to reduce transfusion rates.^{6,25} For patients requiring transfusion during surgery, the protocol recommends restrictive transfusion to a hemoglobin level of 8 g/dl.²⁴ This higher transfusion threshold has been shown to reduce units transfused with no increase in perioperative cardiovascular events, morbidity, or mortality.

Postoperative Recovery and Mobilization

Early Mobilization Program

All postoperative spine surgery patients without contraindication are mobilized by the nursing staff within 8 hours of arriving to the regular nursing floor. If the patient is unable to be mobilized by the nursing staff or is high risk, an order for physical therapy is automatically generated. Removal of the urinary catheter on POD 1 is encouraged to allow for easier mobilization and reduce the

risk of urinary tract infection. Early mobilization has been shown to reduce perioperative complications and decrease the LOS by 34%.¹ A 2009 Cochrane review found strong evidence supporting an intensive exercise program during the postoperative period to increase return to work and improve functional status.⁴³ Additionally, patients mobilized early were more likely to be discharged to home rather than a skilled nursing facility.

VTE Prophylaxis

In addition to early mobilization, it is essential to place postoperative patients on both mechanical and chemoprophylaxis to minimize the risk of developing DVT or VTE. Postoperatively, patients may have prolonged periods of immobilization due to pain, cerebrospinal fluid leakage, or disability secondary to neurogenic compression possibly leading to VTE.⁴⁷ Schoenfeld et al. suggested that patients with high risk factors may require additional attention, including those with BMI greater than 40, those older than 80 years, and those with an operative time greater than 261 minutes. Cox et al. reviewed the results of instituting a new protocol for standardized multimodal VTE prophylaxis, finding that early VTE prophylaxis after spine surgery decreases VTE incidence without increasing morbidity.¹⁰ All patients are started on VTE prophylaxis immediately postoperatively with sequential compression devices, followed by heparin 5000 IU twice daily on POD 2 unless contraindicated.

Methods

The ERAS Program in Clinical Use

Two interventions included in the ERAS protocol have been investigated: initiation of the infection prevention bundle and the perioperative blood management protocol. CCF institutional review board approval was obtained for both.

Infection Prevention

A retrospective cohort study was performed on prospectively obtained SSI data for patients undergoing spine surgery between March 2012 and December 2013. The population was divided into pre- and postintervention cohorts. SSIs were identified using National Healthcare Safety Network definitions. The primary outcome was the incidence of SSI. Data were analyzed using the JMP Pro 10 statistical software package (SAS Institute Inc.). Fisher exact tests, unpaired t-tests, and Wilcoxon tests were used to compare baseline characteristics and rates of infection between preprotocol and postprotocol cohorts. Values of $p < 0.05$ were considered statistically significant.

Blood Management

A retrospective cohort study was performed on prospectively collected data on transfusion rates in patients who underwent multilevel lumbar or thoracolumbar spinal fusions by 3 experienced surgeons piloting the protocol. The population was divided into preintervention (quarter [Q] 1; 2018) and postintervention (Q4; 2008) cohorts. The primary outcome was intraoperative or postoperative blood transfusion. Data were analyzed as above.

Results

Infection Prevention

A total of 1770 patients were included (971 preintervention and 799 postintervention). Forty SSIs were seen in the preintervention cohort and 16 in the postintervention cohort (4.12% vs 2.00%; RR 0.48, 95% CI 0.27–0.86; $p = 0.01$). Following multivariate logistic regression, the intervention was still associated with a decrease in SSI (OR 0.49, 95% CI 0.26–0.87; $p = 0.02$) (Fig. 5).

Blood Management

One hundred fifty-six patients were included in the pilot study. Perioperative transfusion rates fell from 20.1% to 7.7% from Q1 2018 to Q4 2018 ($p = 0.004$), with no appreciable change in morbidity or mortality rates (Fig. 6).

Discussion

Although previous studies have identified the need to improve the management of patients with multiple comorbidities, limited data have been published on the most effective strategies to do so. The effectiveness of any protocol to improve outcomes, efficiency, and patient satisfaction remains to be seen. Preliminary data from our institution have shown that implementation of a multi-tiered approach to improving patient outcomes is possible and may be beneficial.

Implementing the infection prevention bundle has yielded a sustained, statistically significant reduction in postoperative wound infections. It is estimated that this intervention alone resulted in an \$827 cost savings per patient operated on. The effect has been durable as well.

While preliminary in scope, the blood management pathway shows promise with significant reductions in

FIG. 6. Perioperative transfusion rates for major and complex spine surgeries. ERAS protocol was implemented in Q2.

transfusion rates in major and complex spine surgeries. However, the small sample size and limited timeframe of the cohorts limits generalization.

Our experience has shown that the creation of an iterative ERAS protocol is possible; however, there are challenges to implementation and compliance. Implementing the myriad of preoperative pathways was logistically difficult. In order not to disrupt patient flow and practice efficiency, “fast-track” consult pathways needed to be created with the aid of the consulting services to allow for evaluation and optimization in a timely fashion. Without “buy-in” from consultative services, this may not be feasible at other institutions. Monitoring for compliance with protocols is challenging. Monitoring programs needed to be created and required significant resources, which may not be readily available at other institutions. The implementation of multilevel reforms makes analysis for causation difficult with the potential for a variety of confounding factors. The various components of the protocol were introduced

FIG. 5. Quarterly surgical site infection rates pre- and postimplementation of ERAS protocol. Note sustained significant reduction in the infection rate.

in different phases, making the comparison between pre- and postimplementation difficult. Working across multiple disciplines is a potential barrier due to different methods of charting and reduced interspecialty communication. In order to implement all aspects of the protocol, a multidisciplinary team-based approach to care is imperative.

Resources are a significant limitation as surgical spine services vary in capability to include budget, ancillary services, operating room equipment, inpatient consult services and availability, and access to outpatient medical specialists. Our protocol, albeit comprehensive, may not be applicable or feasible for all spine centers. However, given the modular nature of the protocol, portions may be independently implemented.

Our future studies will analyze each segment of the protocol for efficiency, efficacy, and cost-effectiveness. We hope to refine this protocol as our data pool increases to streamline interventions and provide spine surgeons with a standardized system of evidence-based practices that will decrease cost and lower all-cause morbidity and mortality. Subsequent analyses will assess outcomes, including LOS, transfusion rates, 30-day readmission and complication rates, visual analog pain score, infection, and anemia.

Conclusions

We have created and implemented one of the first comprehensive ERAS protocols for spine surgery. Our literature review identified key risk factors and practices that upon intervention would correlate with improved outcomes in spine surgery. Our institution created a multimodal, multidisciplinary approach to simultaneously target these identified areas throughout the surgical episode. Preliminary data have shown improvement in infection and transfusion rates. We believe that standardization is key to improving quality and hope this model will improve outcomes in spine surgery.

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Disclosures

Dr. Krishnaney: consultant for Stryker.

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Conception and design: Krishnaney, Manlapaz. Acquisition of data: Yokoi. Analysis and interpretation of data: Krishnaney, Manlapaz. Drafting the article: Chakravarthy, Yokoi, Coughlin. Critically revising the article: Krishnaney, Chakravarthy, Coughlin, Manlapaz. Reviewed submitted version of manuscript: Krishnaney. Approved the final version of the manuscript on behalf of all authors: Krishnaney. Administrative/technical/material support: Krishnaney. Study supervision: Krishnaney, Manlapaz.

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