Clinical Neurology and Neurosurgery 164 (2018) 142–153

Contents lists available at ScienceDirect

Clinical Neurology and Neurosurgery

journal homepage: www.elsevier.com/locate/clineuro

Pre-optimization of spinal surgery patients: Development of a neurosurgical enhanced recovery after surgery (ERAS) protocol

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ARTICLE INFO

Keywords:
Enhanced recovery after surgery (ERAS)
Major spinal surgery
Multimodal
Clinical outcomes
Patient reported outcomes
Patient satisfaction
Spinal surgery

ABSTRACT

Objective: Despite surgical, technological, medical, and anesthetic improvements, patient outcomes following elective neurosurgical procedures can be associated with high morbidity. Enhanced recovery after surgery (ERAS) protocols are multimodal care pathways designed to optimize patient outcomes by addressing pre-, peri-, and post-operative factors. Despite significant data suggesting improved patient outcomes with the adoption of these pathways, development and implementation has been limited in the neurosurgical population.

Methods/Results: This study protocol was designed to establish the feasibility of a randomized controlled trial to assess the efficacy of implementation of an ERAS protocol on the improvement of clinical and patient reported outcomes and patient satisfaction scores in an elective inpatient spine surgery population. Neurosurgical patients undergoing spinal surgery will be recruited and randomly allocated to one of two treatment arms: ERAS protocol (experimental group) or hospital standard (control group). The experimental group will undergo interventions at the pre-, peri-, and post-operative time points, which are exclusive to this group as compared to the hospital standard group.

Conclusions: The present proposal aims to provide supporting data for the application of these specific ERAS components in the spine surgery population and provide rationale/justification of this type of care pathway. This study will help inform the design of a future multi-institutional, randomized controlled trial.

Results: of this study will guide further efforts to limit post-operative morbidity in patients undergoing elective spinal surgery and to highlight the impact of ERAS care pathways in improving patient reported outcomes and satisfaction.

1. Introduction

Spinal disorders are among the most frequently encountered problems in clinical medicine and can result in significant pain and neurologic dysfunction. Specifically, low back pain (LBP) is one of the most common health problems worldwide and affects as many as 80% of people at some point in their lifetime, with 1% to 2% of the United States adult population disabled because of LBP [34]. In particular, LBP is the second most common cause of adult disability in the United States with prevalence greater than that due to heart conditions, stroke, and cancer combined [22].

Direct medical costs to insurers, patients, and families as well as indirect cost estimates to the health care system, insurance companies, and society from loss of work productivity demonstrate the significant socioeconomic problem created by degenerative spinal disease [28,108]. Approximately 9% of all health-care cost is attributed to spine pain in the United States, and the total cost of low back pain exceeds $100 billion per year in the United States alone [69]. Two-thirds of these costs are related to lost wages and decreased productivity at work. Indeed, this population endorses worsening self-reported measures of mental health, physical functioning, work or school limitations, and social limitations over time [92]. In addition, complication rates, including mortality, associated with treatments for spinal disease are on the rise.

Though significant advances have been made in neuroanesthesia and peri-operative neurosurgical care, spinal surgery still often results in significant post-operative morbidity. Excluding complications related to anesthesia or surgery, the surgical stress response, with its increased metabolic demands on the body, serves as a critical pathogenic factor in post-operative morbidity. Introduced in 1997 by Henri Kehlet, Enhanced Recovery after Surgery (ERAS) proposes a multimodal, evidence-based approach to prepare patients for surgery [71]. The

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https://doi.org/10.1016/j.clineuro.2017.12.003
Received 29 September 2017; Received in revised form 21 November 2017; Accepted 2 December 2017
Available online 08 December 2017
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Fig. 1. ERAS is a novel protocol in the elective neurosurgical spine patient that aims to improve patient satisfaction as well as patient reported and clinical outcomes.

principles of ERAS have been implemented for a variety of surgeries such as colonic [52], pancreaticoduodenectomy [80], cystectomy [23], gastrectomy [95], and rectal/pelvic surgery. [98] The evidence to support ERAS in major spinal surgery has been proposed previously and implemented in a minimally invasive lumbar fusion population most recently [133,134]. Application of ERAS in the neurosurgical arena has the potential to enhance productivity gains and cost savings. However, explicit guidelines are lacking for the neurosurgical spinal patient population. We propose the first American randomized controlled prospective clinical trial to assess the feasibility and efficacy of a novel ERAS protocol in the neurosurgical spinal population in order to improve patient satisfaction as well as patient reported and clinical outcomes (Fig. 1).

2. Design

2.1. Recruitment

Participants will be recruited within the University of Pennsylvania Health System following the neurosurgical outpatient clinic visit in which the patient is recommended to undergo elective spinal surgery based on clinical criteria. If the patient meets eligibility criteria, he or she will be provided with an overview of the study objectives and design. The patient will undergo informed consent and randomization.

2.2. Eligibility criteria

The inclusion criteria include: clinical history and diagnostic imaging that support the need for elective inpatient spinal surgery, age over 18 years without an upper age limit, and the ability to understand and actively participate in the program as deemed by the study team. The exclusion criteria include: contraindications to elective spinal surgery, liver disease, and pregnancy.

2.3. Randomization

Patients will be randomized following a computer-generated list of random numbers. An independent research assistant blinded to the patient assignment will sequentially number the envelopes containing intervention assignments according to the computer-generated randomization. Opaque and sealed envelopes will be opened in front of the participants at the end of the initial assessment visit. Patients will be randomly allocated to one of the two following groups: 1) experimental group (ERAS protocol), and 2) control group (hospital standard management).

2.4. ERAS pathway

The ERAS pathway will be divided into three distinct chronological time periods: pre-op (Fig. 2), peri-op (Fig. 3), and post-op (Fig. 4). The components of each stage will be reviewed here.

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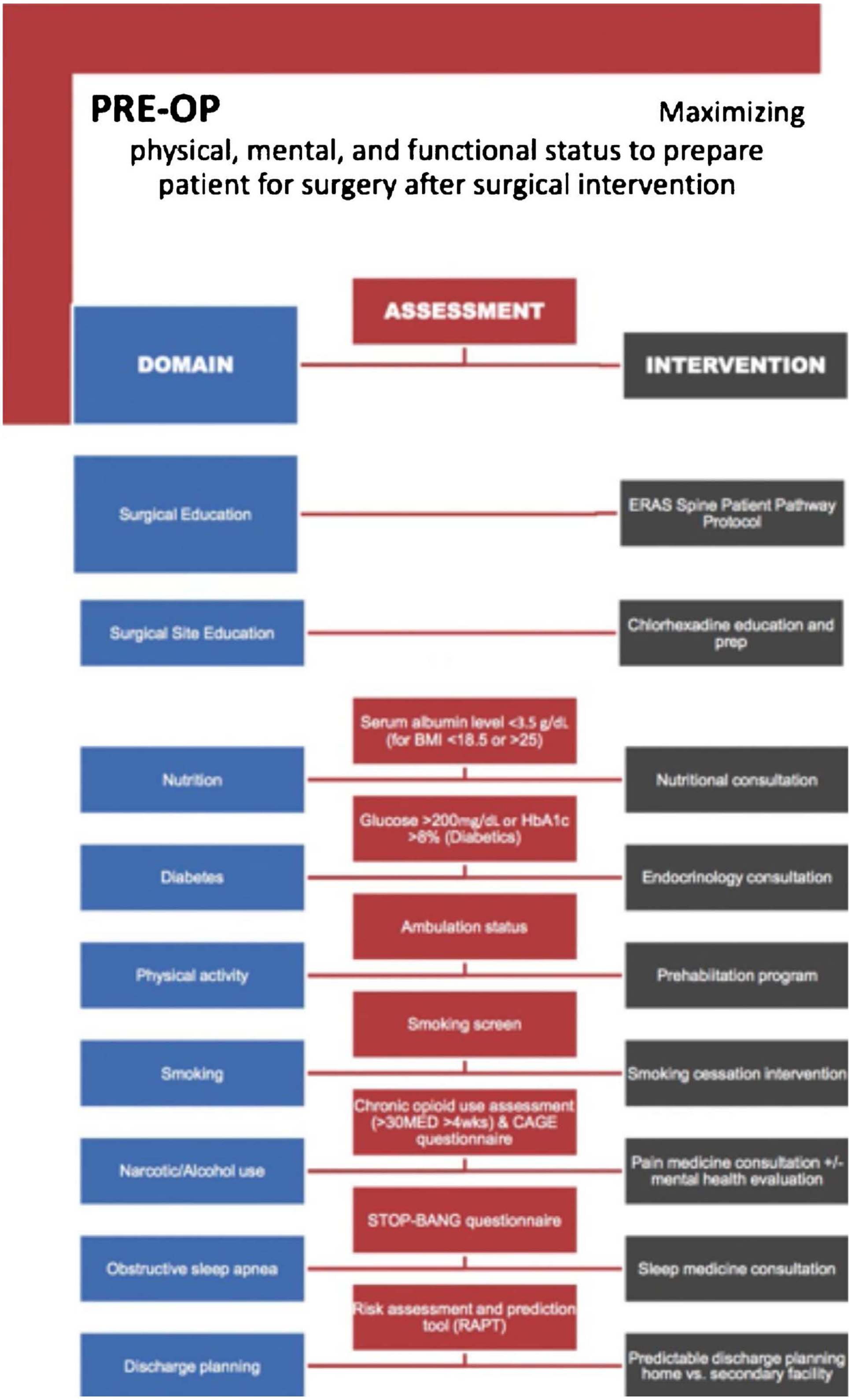

Fig. 2. illustrates the components of the pre-operative branch of ERAS. In the pre-oprative period, it is important to maximize the various physical mental, and functional elements of the patient to prepare for surgical intervention.

2.4.1. Pre-op

The pre-op portion of the proposed ERAS protocol focuses on optimizing the neurosurgical spinal patient prior to surgery, i.e. "pre-optimization." The goal of pre-operative care is to maximize the physical and functional status of the patient prior to surgical intervention as well as to engage and educate the patient about surgical expectations. The timeline for this portion of the ERAS protocol is variable, for each patient is unique with his or her own singular set of medical co-morbidities. The time required for appropriate pre-operative risk stratification and pre-optimization may range from days to weeks.

2.4.1.1. Patient surgical education. In addition to educating the patient on surgical risks, benefits, and alternatives to surgery as part of the typical informed consent process, the Neurosurgery ERAS protocol

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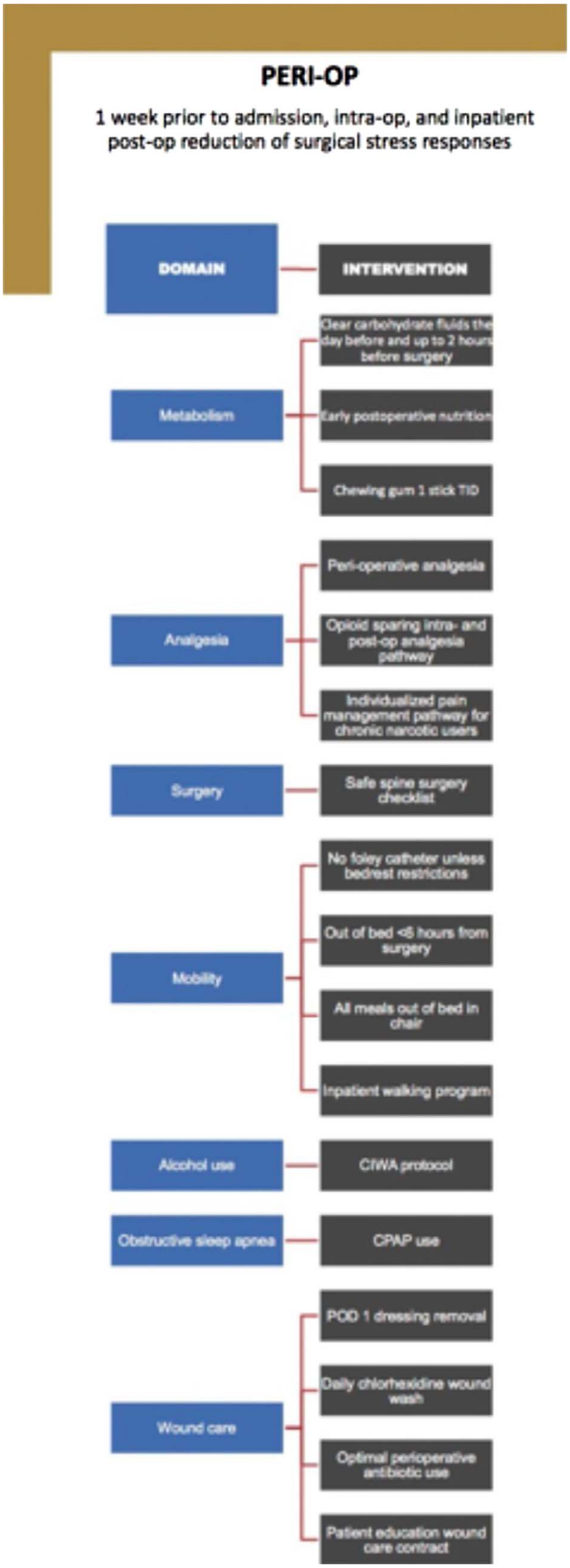

Fig. 3. outlines the peri-operative component of ERAS, which involves 1 week prior to admission, the intra-operative period, and the inpatient experience. The goal is to reduce the surgical stress response.

utilizes an ERAS Spine Patient Pathway Protocol to provide a guide for the patient about the surgical journey. Specifically, the protocol includes information about necessary appointments and consultations prior to surgery, expectations about post-operative disposition, details on pre-admission testing, pre-operative medication use, peri-operative eating and drinking, instructions before surgery, surgical site care and cleansing education, and information on post-operative appointments.

2.4.1.2. Surgical site education. Bacterial skin flora present at the operative site is a potential risk factor for surgical site infection in spinal surgery. An antimicrobial skin preparation solution prior to surgery may serve to decrease bacterial load at the time of incision. Specifically, chlorhexidine gluconate (CHG) has also been shown to decrease surgical site infections rates [37]. The use of CHG is a standard pre-operative practice across various surgical specialties due to the logical belief that pre-operative bathing reduces skin bacterial load [67,132]. Currently, the standard practice at the authors' institution is to provide patients with CHG solution and instructions on washing the operative site for three consecutive nights before surgery as well as the morning of surgery. However, there is no standard for monitoring compliance of this protocol. As part of the ERAS protocol, patients will receive surgical site care instructions and also be monitored for compliance.

2.4.1.3. Nutrition. Nutrition is a significant modifiable risk factor, particularly in the neurosurgical spinal patient population. Most spinal disease occurs in the aging population, which is at an increased risk of protein-energy malnutrition as a result of physiologic/anatomic changes, chronic diseases, poor dietary/ psychosocial habits, and habitual use of multiple medications [35]. The magnitude of a surgical procedure directly impacts caloric and protein requirements [89]. Pre-operative malnutrition, as defined by serum albumin level < 3.5 g/dL, has been shown to present an independent risk factor for unplanned re-admission within 30 days after discharge after elective spine surgery [3] and spinal fusion for degeneration and deformity cases [4]. Pre-operative hypoalbuminemia in anterior cervical discectomy and fusion (ACDF) surgeries was also found to be an adjunct predictor of major complications, i.e. cardiopulmonary problems and re-operation [45]. A clear relationship has been established between spinal surgical site infections and nutritional depletion [90]. Pre-albumin levels of less than 25 mg/dL, retinol-binding protein levels less than 3 mg/dL, and transferrin levels less than 230 mg/dL have also been associated with infectious complications in patients undergoing major elective surgery (abdominal aortic aneurysmal resection, thoracic surgery with thoracotomy, and proctologic/pancreatic surgeries) [35]. A significant post-operative decrease in nutritional parameters such as protein, albumin, serum albumin, transferrin, and lymphocytes has been seen in patients undergoing surgery for idiopathic scoliosis [78]. Well-documented risk factors for nutritional depletion in spinal surgery have included: age over 50 years, [75,85] diagnosis of cerebral palsy [63], circumferential spinal surgery [75,85], and fusion levels greater than or equal to 10 [63]. Though previously reported studies on nutritional status in the spinal patient have incorporated heterogeneous patient populations, the authors suggest that recognition of nutritional status pre-operatively can guide pre-operative interventions that may translate into improved post-operative patient satisfaction and clinical/functional outcomes. Specifically, the authors propose pre-operative nutritional consultation and education for those high-risk patients identified body mass index (BMI) < 18.5 or > 25 with a pre-operative serum albumin level < 3.5 g/dL.

2.4.1.4. Diabetes. Diabetes is found in 5–20% of all patients undergoing spinal surgery and is associated with poor post-operative outcomes such as reoperation and infection as well as prolonged hospital stay

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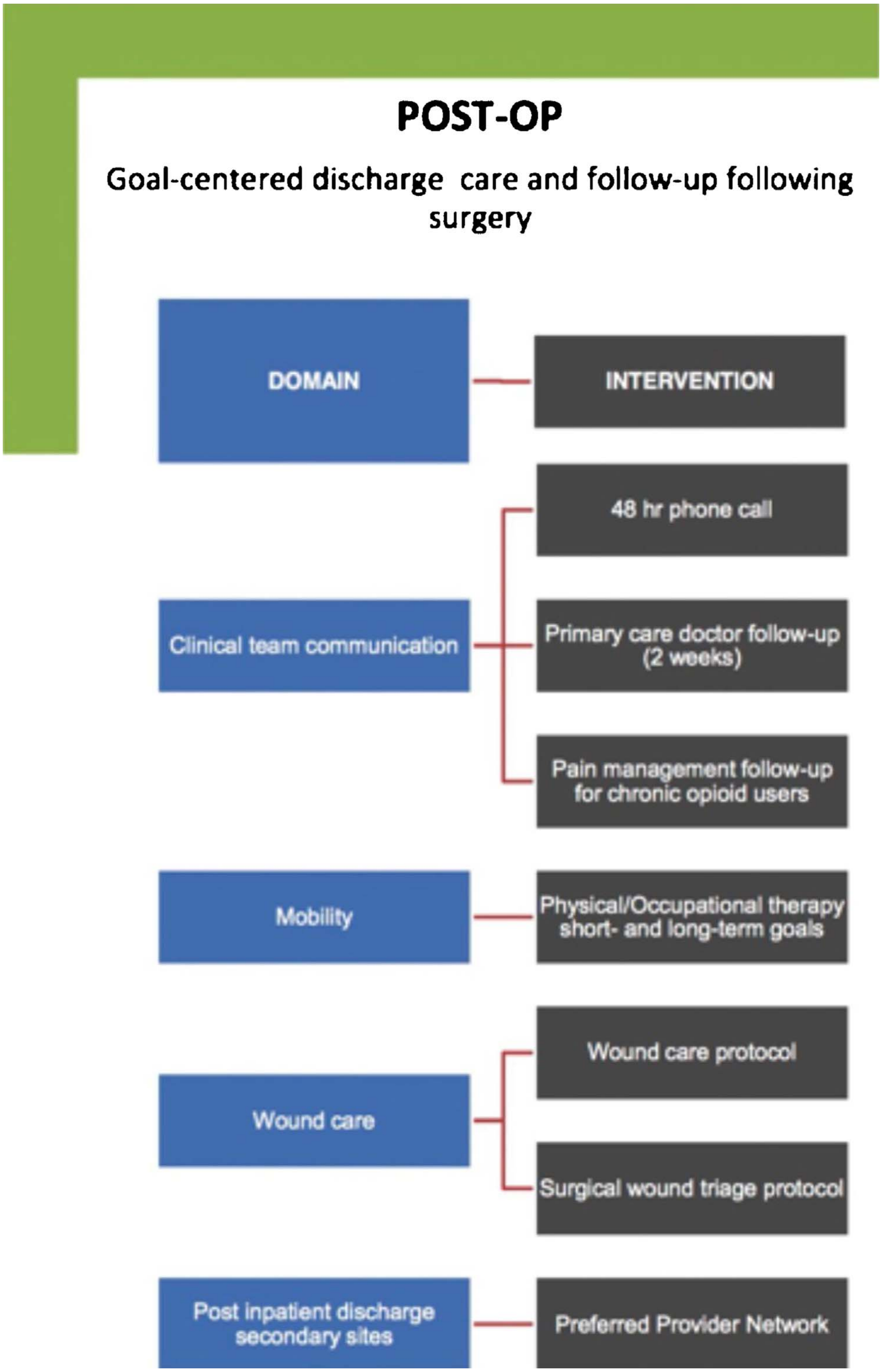

Fig. 4. illustrates the post-operative elements of ERAS, which focuses on goal-centered discharge care and outpatient follow-up care.

[17,123]. Diabetes contributes to impaired leukocyte function, microvascular dysfunction, and hyperglycemia, which propels the body into an immunocompromised state and increases the risk of infection [48,107]. The co-morbidity of diabetes predicts worse patient-reported outcomes at two years after elective spinal surgery using the Oswestry Disability Index (ODI) and EuroQol five dimensions questionnaire (EQ5D) [8]. Patients with diabetes may have a lower baseline functional status than those patients without diabetes, which may directly impact post-operative recovery. Hemoglobin A1c (HbA1c) is a measure of chronic diabetes control, and its measurement in the pre-operative setting offers invaluable insight into the severity of a patient's diabetes. The authors propose that patients with known diabetes and HbA1c > 8% or all patients with random serum glucose > 200 mg/dL should undergo specialty consultation with an endocrinologist to obtain tighter glycemic control prior to spinal surgery.

2.4.1.5. Physical activity. Patient activation represents a patient's likelihood of engaging in adaptive behaviors to improve his or her own outcome and is directly associated with better recovery after

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surgery through increased adherence to physical therapy [115]. Pre-operative physical therapy or rehabilitation prior to surgery, known as "prehabilitation," is a practice that may positively influence post-operative function and recovery. There are several studies that are currently examining the role of prehabilitation in spinal surgery [86,88,91,112]. The authors propose that prehabilitation in spinal surgery patients has the potential to improve post-operative function and recovery. The authors propose assessing the ambulation status of all patients and then enrolling patients in a prehabilitation program for 6–8 weeks prior to surgery.

2.4.1.6. Smoking. Smoking is a well-established, independent risk factor for non-union in spinal procedures [6,16,18,49,94]. Tobacco-related inhibition of bony fusion is thought to be a result of a decrease in systemic bone mineral density, osteoblastic cellular metabolism, and local blood flow/angiogenesis [54]. Tobacco increases the risk of post-operative wound complications and infection, which is associated with increased costs, longer length of stay, and higher rates of secondary surgeries [19,102,120]. Smoking cessation has been found to improve significantly spinal surgery patient outcome scores regarding pain, functional status, progress after surgery, and post-operative satisfaction [20]. Of patients who underwent posterior instrumented fusion, those who quit smoking returned to work at a statistically significantly higher rate than those who did not quit smoking, even when cases of non-union were excluded (i.e. higher rates of pseudoarthrosis in those who did not quit does not completely explain the difference) [49]. Pre-operative smoking cessation for even just 4 weeks is associated with a decreased risk for infection, peri-operative respiratory problems, and wound complications [59,77,120,135]. The authors predict that the incremental benefits of inclusion of a mandatory 4-week smoking cessation period with cessation aids and appropriate counseling will improve the post-operative outcomes of spinal surgery patients.

2.4.1.7. Narcotic/alcohol use. Approximately 3–4% of the adult US population is prescribed long-term opioid therapy [14]. Long-term opioid use is controversial given the implications of analgesic tolerance and drug dependence [44,128]. Chronic opioid users undergoing cervical and lumbar fusions have been found to experience worse outcomes post-operatively compared to patients who do not use chronic opioids pre-operatively [82,131]. Therefore, we propose that all patients using > 30 morphine equivalent dose (MED) for more than 4 weeks undergo evaluation with a pain management physician to aid in developing an individualized pain management protocol that aims to reduce opioid dependence.

The CAGE questionnaire was introduced as a fast and efficient tool for the physician to discern alcohol abuse in patients [41]. Alcohol intake is a risk factor for post-operative complications, and patients who suffer from alcohol abuse are at increased risk for infections, pulmonary complications, prolonged hospital stay, and admission to the intensive care unit [38,124]. Pre-operative alcohol cessation interventions with the use of a pharmacological treatment for relapse prophylaxis and withdrawal treatment has been found to significantly reduce post-operative complication rates [103]. The CAGE questionnaire will be applied during the pre-operative clinic visit to screen for those patients who may benefit from further interventions and mental health evaluation and counseling to directly address alcohol abuse and addiction prior to elective spine surgery.

2.4.1.8. Obstructive sleep apnea. Obstructive sleep apnea (OSA) is a chronic disease of anatomic collapse or partial obstruction of the upper airway during sleep. The cervical spine provides mainly passive support despite the fact that the pharyngeal musculature is attached to the vertebral column [122]. Endogenous cervical fusions have been reported in OSA patients, though the mechanism of apnea is not well understood but thought to be related to poor head posture and craniofacial morphology [56,118,135]. Occipital-cervical alignment may also be a factor in OSA [73]. OSA is associated with a variety of post-operative complications such as unplanned ICU stays, re-intubations, pulmonary emboli, and serious cardiac events [51,58,70,93]. The STOP-BANG questionnaire (SB) is a simple, well-validated method of screening surgical patients who may have OSA, and a score greater than 2 as predictive of OSA with a high sensitivity (93% moderate OSA, 100% severe OSA) albeit low specificity (47% moderate OSA, 37% severe OSA) [25,26]. The authors propose the use of the SB as a screening tool for referral for pre-operative sleep medicine consultation in patients who screen positive. The authors believe that this will reduce the risk of post-operative pulmonary complications related to undiagnosed OSA.

2.4.1.9. Discharge planning. Health care providers recommend discharge to home, a skilled nursing facility (SNF), or an acute rehabilitation facility on a subjective case-by-case evaluation that is usually confirmed early in the post-operative period. The Risk Assessment and Prediction Tool (RAPT) is a valid and reliable method of predicting discharge destinations and helps patients as well as hospitals confidently plan for post-operative management [101]. Though it was originally established for elective hip or knee arthroplasty [101], the RAPT has also recently been successfully applied to spinal surgery patients as well [116]. Increasing pre-operative risk assessment to determine optimal discharge destination establishes appropriate support measures to allow for required discharge planning. Discerning those patients who are at risk for discharge to a secondary facility provides a smoother transition to outpatient care. The authors propose use of the RAPT assessment at the pre-operative clinic visit to establish the patient's and the patient's family's expectations for post-operative disposition. This tool can aid in maximizing alignment of patient expectations and minimizing re-admissions.

2.4.2. Peri-op

The peri-op portion of the ERAS protocol focuses on the time period one week prior to admission, the intra-operative period, and the immediate post-op period. The goal in this period is to reduce significantly the surgical stress response.

2.4.2.1. Metabolism. The stress of surgery can induce a physiologic state of insulin resistance and hyperglycemia that is associated with increased post-operative morbidity and mortality [129]. Elective surgery is often preceded by a 12-h fast in order to decrease the risk of pulmonary aspiration. However, fasting results in a catabolic state that then contributes to insulin resistance [98–100]. Patients who receive a pre-operative glucose infusion have less protein breakdown and reduced post-operative insulin resistance [27,87]. The use of a carbohydrate supplement has the same metabolic benefits as a pre-operative glucose infusion [96,97,119]. The use of pre-operative carbohydrate (CHO) supplements has been found to be safe and effective in colorectal surgery without increased risk of aspiration and has also been associated with a shorter hospital stay [65]. Further, chewing gum in the post-operative period has the potential to decrease the risk of ileus via stimulation of the cephalovagal system and intestinal motility as well as encouragement of pancreatic juices/saliva [29,47,62]. To this end, the authors propose clear carbohydrate fluids the day before and up to two hours prior to elective spinal surgery, early post-operative nutrition, including a regular diet on post-operative day one, and a regimen of one stick of chewing gum three times daily post-operatively.

2.4.2.2. Analgesia. Pain is a common and expected occurrence after surgery due to inherent tissue manipulation. There is growing evidence that pain may be inadequately and inappropriately managed in many patients [57]. Patients with a history of chronic opioid use experience a greater severity of acute pain and slower resolution of pain despite

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adjustments for additional opioid administration [24]. Preemptive analgesia aims to prevent post-operative pain through central autonomic hyperactivity inhibition. These types of medications and agents include regional anesthesia, nonsteroidal anti-inflammatory drugs (NSAIDs), opioids, anti-convulsants, and acetaminophen. Patients undergoing preemptive analgesia exhibit improvement in immediate post-operative pain, usual activity, depression/anxiety, and self-care at 2 weeks post-operatively [84]. The authors propose the use of 600 mg gabapentin immediately

pre-operatively (except for patients with creatinine clearance < 15 mL/min) as well as standing around the clock acetaminophen post-operatively (975 mg every 6 h, unless liver disease is present). Intravenous and oral narcotics are only used on an "as needed" basis. In addition, standard use of local anesthetics such as intradermal lidocaine will be implemented at the time of surgical closure of the wound. Muscle relaxants such as diazepam and cyclobenzaprine and ketorolac are also used as needed as adjuncts for pain control. This is a dramatic shift from the traditional post-spinal surgery practice in which patient controlled analgesia using opioids is the standard post-operative pain management regimen. In chronic opioid users, the intra-operative and post-operative pain management regimen, as determined by pain management consultation pre-operatively, will be adapted.

2.4.2.3. Surgery. Implementation of surgical safety checklists has resulted in favorable outcomes for patients [55,74,83,136]. Significant reductions in both mortality and complication rates have been reduced by the adoption of checklists. However, despite the known benefits of adoption of surgical checklists, few exist in neurosurgical procedures. The authors propose a Safe Spine Surgery checklist (Table 1) in which prior to wound closure, attention is directed to ascertain if all necessary components of the spinal surgery and complication prevention techniques were employed, including decortication and final tightening of hardware for fusion procedures, wound irrigation, hemostasis, and placement of drain(s), if needed.

2.4.2.4. Mobility. Fear-avoidance is a cognitive-behavioral phenomenon that fear of pain leads to avoidance behaviors that result in deconditioning and depression, which further perpetuates pain [50,79]. Pre-operative fear of movement is a strong predictor of low quality of life (QOL) at 12-month follow-up and increased pain/disability at six-month follow-up in patients who undergo lumbar disc surgery [30,31,64]. Similarly, it has been established that there is a significant correlation between pre-operative fear of movement and pre-operative pain, disability, and QOL outcomes after lumbar spinal fusion [2]. Post-operative fear of movement is also strongly associated with pain, disability, and physical health at six weeks and three months after laminectomy with or without arthrodesis [7]. Addressing fear of movement early in the post-operative period aims to reduce significantly immobility and enhance post-operative recovery. The authors propose mobilizing the patients within six hours post-operatively, provided no activity restrictions exist. In addition, all meals are encouraged out of bed in a chair to encourage mobilization.

Table 1
Safe Spine Surgery Checklist.

1. Decompression/Stabilization/Reconstruction & Realignment
2. Neuromonitoring assessment
3. Final imaging
4. Final screw tightening
5. Antibiotic irrigation
6. Decortication & apply bone graft
7. Secure hemostasis and place drain
8. Vancomycin powder application
9. Final neuromonitoring assessment
10. Local anesthetic
11. Closure
12. Check drain

Post-operative urinary retention (POUR) increases length of stay and increases pain and morbidity [9,104]. POUR risk factors include posterior lumbar surgery, benign prostatic hypertrophy (BPH), chronic constipation, prior urinary retention, patient-controlled analgesia pump use, lengthy operative time, diabetes, and depression [5,46]. Avoiding the use of Foley catheters is a major goal during the inpatient period for those patients not requiring bed-rest restrictions. Aggressive bladder scanning and encouraging voiding regimens after spinal surgery may serve to significantly decrease POUR, especially when combined with early and aggressive mobility. The authors propose the use of a temporary Foley catheter only in the setting of expected operative time of greater than two hours with plan for removal immediately following surgery. Indwelling Foley catheters are used and maintained until post-operative day one for all patients with bed rest precautions due to spinal leak, more than three levels of thoracic or lumbar fusion, or other medical or urologic necessity.

2.4.2.5. Alcohol use. While the CAGE questionnaire aims to discern patients with alcohol abuse in the pre-operative period, the Clinical Institute Withdrawal Assessment for Alcohol protocol (CIWA) allows assessment of alcohol withdrawal severity when the patient is admitted to the hospital [121]. CIWA has been shown to manage safely alcohol withdrawal as well as to prevent overtreatment with a benzodiazepine [111]. Implementation of CIWA has been associated with a reduced average daily and cumulative dose of diazepam in alcohol withdrawal as well, which implies a higher safety profile with the use of CIWA [36]. Therefore, for those patients who do not successfully overcome their alcohol abuse and dependence in the outpatient setting, the authors propose implementation of the CIWA protocol after spinal surgery while the patient is in the hospital.

2.4.2.6. Obstructive sleep apnea. The SB questionnaire has been found to predict accurately the risk of intraoperative and early post-operative adverse events in patients with OSA [113]. SB also identifies OSA patients at risk of an increased length of hospital stay due to complications from their airway status [106]. The questionnaire efficiently identifies patients with occult OSA, which decreases the rate of post-operative complications related to OSA [130]. Those patients who were identified in the pre-operative setting at risk for OSA using the SB questionnaire will have completed a sleep medicine evaluation. Recommendations from this clinical evaluation will be instituted while the patient is in the hospital to prevent post-operative morbidity related to hypoxemia.

2.4.2.7. Wound care. Surgical site infections (SSI) after spinal surgery occurs at a rate of 0.7–12.0% [1,72,102,109]. The authors propose removal of the surgical dressing on post-operative day one in order to adequately assess the surgical incision to prevent infection caused by neglect of the operative site. The current peri-operative antibiotic protocol for spinal surgery at the authors' institution includes the administration based cefazolin (1 mg/kg) to be initiated within 30 min of incision and every 6 h for 2 additional doses. In penicillin-allergic patients, vancomycin (15 mg/kg) infusion is started within 30 min of incision and once 12 h afterwards. In addition, the authors recommend the addition of daily chlorhexidine wound washes while in the hospital to decrease SSI. A patient education wound care contract that is established with the patient prior to discharge further aims to enhance post-operative wound care.

2.4.3. Post-op

The post-op portion of the ERAS protocol focuses on the time period following inpatient discharge from the hospital. The goal in this period is to incorporate goal-centered care and follow-up after surgery.

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2.4.3.1. Clinical team communication. Direct patient communication in the post-operative period after a patient is discharged from the hospital is critical to the continuity of patient-centered care. The authors propose a phone call from the surgical advanced practice provider within 48 h of discharge to assess pain management, identify patient concerns regarding mobility, and clarify post-operative follow-up instructions In addition, the authors propose routine follow-up with primary care doctors within 1–2 weeks after surgery for those patients who required pre-operative medical or cardiac evaluation. Similarly, those patients who required pre-operative pain management consultation are encouraged to follow-up with these providers in the post-operative setting to ensure adequate pain management. The authors believe that the engagement of both patient and providers following surgery is critical to maximize both clinical and functional outcomes after surgery. In addition, the emotional bond established by the patient and surgical team is further reinforced.

2.4.3.2. Mobility. For patients who are not limited to restricted activity precautions post-operatively, post- operative mobility is encouraged. The authors propose the use of inpatient physical or occupational therapy evaluation's short- and long-term goals as a starting point for achieving further mobility milestones. This may be supplemented by continued outpatient or home physical therapy in patients who are discharged to home.

2.4.3.3. Wound care. Upon discharge, all patients are requested to see their surgical provider or primary care doctor to evaluate wound healing and identify any issues associated with the surgical site within 10–14 days after surgery. The authors' experience with barriers to proper wound care includes misunderstanding of the process and lack of knowledge of the frequency of wound washing. To this effect, the authors have developed a standardized wound washing protocol, which is distributed to both patients and family members upon discharge from the hospital as well as to post-acute care facilities, including skilled nursing facilities and rehabilitation centers. This includes specific instructions on daily wound washing. In addition, the authors have developed a communication triage protocol in which wound care issues that arise in post-acute care facilities, such as rehab centers or skilled nursing facilities, may be triaged via phone conversation with advanced practice providers and/or outpatient clinic evaluation rather than Emergency Room transfer or re-admission to the hospital.

2.4.3.4. Post-acute care secondary sites. When the disposition of patients requires inpatient rehabilitation services or skilled nursing facility admission, the authors' experience has been that communication with the surgical team and adherence to outpatient and inpatient goals is fragmented. No current system is in place to monitor and communicate patients' progress in this setting with other care team members. As such, the authors have adopted the development of a "Preferred Provider Network" as part of the neurosurgical ERAS initiative. The Network is developed based on favorable data from prior patient admissions. Specifically, this includes meeting expectations for estimated lengths of stay, limited number of re-admissions, compliance with wound care and mobility goals, etc. Bundle payments create an incentive for physicians and hospitals to hold post-acute care sites accountable for the care provided given that costs associated with hospital re-admission from these sites are not negligible.

2.4.3.5. Conventional surgical care. The traditional approach to surgical spine care has included a thorough assessment by the neurosurgeon to determine if the patient requires elective spinal surgery. Once this decision is made, the patient undergoes medical and/or cardiac evaluation and risk stratification prior to surgery. Any recommendations by the medical or cardiac specialist are typically enforced and then the patient is scheduled for surgery. Rarely, in cases of complex medical co-morbidities, such as bleeding diathesis, subspecialty evaluations are sought pre-operatively. In general, no standardized nutritional screening parameters, diabetes evaluation, smoking cessation program, narcotic assessment, OSA evaluation, or pre-operative discharge planning is incorporated into the pre-operative preparation of patients for surgery.

In the peri-operative setting, traditional approaches have called for patients to fast prior to surgery. In addition, post-operative advancement of diet is generally encouraged but often at a limited fashion and in a slow rate. As far as analgesia, generally all spinal surgery patients were given patient controlled analgesia using intravenous morphine or hydromorphone followed by oral narcotics. No intra-operative checklist exists to ensure all components of surgery are verified prior to skin closure. As far as mobility, Foley catheters are typically used in patients undergoing spinal surgery, which dramatically limits mobilization. In addition, no specific goals for mobilization on post-operative day zero are set. Meals are oftentimes in bed, thereby encouraging less motion. Ileus prevention is also not standardized. For wound care, all dressings are generally removed on post-operative day one, and daily wound washes are recommended. However, the compliance of wound care and the optimal administration of peri-operative antibiotics have not been aggressively followed. Current hospital standard does not require the use of CPAP in patients with OSA following spinal surgery as well as the use of CIWA protocol in patients with alcohol dependence/abuse. However, no pre-operative mechanism is in place for identifying patients with these undiagnosed conditions.

2.4.3.6. Outcome measures. The primary outcome measures studied will include responses from patient reported outcome measures. Well-validated questionnaires provide both the patient and clinician insight into the pre-operative perception of the patient's pain, disability, personal care, walking ability, social life, and anxiety/depression. The Patient-Reported Outcomes Measurement Information System (PROMIS), Oswestry Disability Index (ODI), Visual Analogue Scale (VAS), and EuroQol five dimensions questionnaire (EQ5D) will be administered in the pre- and post-disease-associated disability. Patient reported outcomes have become the gold standard to measure clinical efficacy after a surgical intervention [13,105,126,127]. These questionnaires will be utilized at the initial outpatient encounter, and at one month, three months, and six months post-operatively.

Anxiety and depression may negatively impact surgical functional outcome. However, routine assessment of these mood disorders is not commonly employed in the spinal surgery pre-operative evaluation. Pre-surgical emotional status is a significant prognostic predictor of outcomes in pain and function in spinal fusion surgery [125]. Psychological and emotional stress can negatively impact post-operative outcome in patients with chronic low back pain undergoing lumbar fusion [33]. Developed by a collaborative initiative funded by the National Institutes of Health, PROMIS is a rapid and precise assessment of mental and physical health [10,21]. Given that the importance of psychological factors in spinal surgery outcome is now well recognized [32], PROMIS may afford the neurosurgeon a risk stratification tool to redirect patients who may benefit from pre-operative outpatient psychiatric assessment/intervention prior to spinal surgery.

First published in 1980 by Fairbank et al. [43], the ODI is the most commonly used questionnaire measuring the extent of disability related to low back pain and spinal surgery [68]. The test has been adapted for use in patients in several non-English speaking nations [114], and has since been modified from its original version [42,110]. The ODI consists of ten items that represent different health constructs such as pain intensity, physical function, sleep function, and social function. As the most commonly used outcome measure for spinal disease, the ODI has shown to have good content validity, internal consistency, and face validity [12,76].

Since its inception by Woodforde and Merskey in 1972 [137], the

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VAS serves as a reliable measure of a patient's degree of pain. A higher prevalence of known secondary gain among patients with maximum reported pain has been found when compared to other patients [11]. The VAS is reported as one of the most frequently utilized instruments to assess spinal surgery patients [53].

The EQ5D is a standardized questionnaire to measure generic health status utilizing quality-adjusted life years (QALYs). Created by the multi-country and multi-center EuroQol Group in 1990, the EQ5D complements other quality-of-life measures in order to develop a non-disease-specific instrument to describe health states [40]. The questionnaire generates a cardinal index of health from a questionnaire that is completed by the patient. It is comprised of four sections: [15] 1. description of the patient's own health in mobility, self-care, usual activities, pain/discomfort, and anxiety/depression; 2. rating of the patient's own health from 0 ("worst imaginable health state") to 100 "(best imaginable health state"); 3. valuation of a standard set of health states on a scale from 0 to 100; and 4. background information about the patient such as occupation/activity, age, sex, education, etc. The index score derived from the general population sample is an assessment of the societal valuation of the patient's health state. The EQ5D has been adopted within spinal surgery [61,117] and other orthopedic procedures [60] as a comprehensive assessment of the patient's overall health state.

Secondary outcome measures will include length of hospital stay, post-operative duration of pain medication usage, rate of re-admissions, home disposition rates, Activity Measure for Post Acute Care (AM-PAC) scores, patient satisfaction score, duration of post-acute care services and admissions, deaths, morbidities, complication rates (including surgical site infections, urinary tract infections, cardiopulmonary events, wound dehiscence rates, and non-union rates), and overall cost.

3. Discussion

A neurosurgical ERAS pathway that focuses on optimizing the pre-, peri-, and post-operative care of patients can lead to quicker and more efficient recovery, thereby reducing hospital length of stay and hospital costs. Lack of coordination among teams (outpatient staff, anesthesia team, surgical team, in-house ward staff, etc.) may contribute to diminished quality of care in a patient's surgical course [66]. To prevent this, ERAS is designed to involve and engage all health care providers in the patient's surgical journey in a longitudinal fashion. The present protocol is designed to establish the feasibility of a randomized controlled trial to assess ERAS implementation in the elective spine surgery population.

The use of an ERAS pathway has recently been shown to be possible and successful in spinal fusion patients who underwent minimally invasive surgery without general endotracheal anesthesia [134]. The present proposal encompasses all spinal surgery patients in order to understand better the population(s) that most benefit from this type of 360 ° care approach. The underlying theme of ERAS involves optimizing pre-operative organ function and reducing the dramatic stress response following surgery. Indeed, improved surgical outcomes have been demonstrated with the implementation of ERAS in other disciplines [39,81].

Neurosurgical pre-operative and peri-operative care continues to resemble traditional approaches. The authors hypothesize that successful integration of ERAS principles predicts improved recovery as measured by both patient reported outcomes as well as clinical and functional parameters. The implementation requires a multi-disciplinary, multi-modal approach, including and involving pre-admission staff, dieticians, nurses, physical and occupational therapists, social workers, surgeons, and medical physicians. The incremental benefits accrued from each component of the current protocol has the potential to translate into meaningful patient recovery following spinal surgery and to improve the delivery of spinal care and patient satisfaction. The authors appreciate that as the population ages, the surgical spine population also presents at an advanced age with multiple co-morbid conditions. This recognition calls for the review of current traditional surgical practices and the need for more thoughtful and comprehensive care pathways for patients in order to reduce morbidity.

3.1. Barriers to implementation

The current neurosurgical ERAS protocol requires a multi-faced approach to patient care. The full effect of such a protocol requires the compliance and engagement of all parties, including the patient, surgeon, and all other providers in each domain of care. Maximal benefits are unlikely if there is fragmented compliance or adoption of practices. One of the main criticisms of this revolutionary approach to patient care includes the recognition of delaying surgery in those patients who may benefit from additional consultation services. Since surgery is limited to only those patients undergoing elective, non-urgent, non-emergent neurosurgery, this is acceptable but greatly challenges the dogma of traditional practice. The authors argue that in the long-term, the benefits accrued from optimizing patients prior to surgery is far greater than any loss in short-term deferral of surgery.

4. Conclusion

The present study will guide future efforts to minimize post-operative morbidity and mortality in elective spinal surgery patients. The value of spinal care depends on delivering both patient satisfaction and improvement in clinical and functional outcomes. ERAS provides a platform to engage all parties associated with a patient's surgical journey to optimize outcome in a multi-disciplinary, multi-modal approach that challenges traditional approaches. The authors argue that this is both feasible and necessary for the future of spinal surgical care.

Funding

We would also like to thank the brahams Family Innovation Fund, which granted funding for the creation of the illustrations presented in this manuscript.

Acknowledgments

We would like to thank Eileen Maloney Wilensky and the Neurosurgery Clinical Research Division, who contributed to the development of the ERAS protocol.

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