Review Article

Comprehensive guidelines for prehabilitation in spine surgery

ABSTRACT

Study Design: Literature review.

Objectives: Review prehabilitation techniques used for elective spine surgery to create a comprehensive list of recommendations.

Methods: A systematic review was performed using the Preferred Reporting Items for Systematic Reviews and Meta-Analysis guidelines by searching three electronic databases from 1997 to 2021. Pertinent literature reporting information on prehabilitation, applicable to spine surgery, was identified. Seventy studies were selected for further analysis. Findings from the literature were reinforced by practices employed by the authors.

Results: Preoperative smoking cessation should be achieved 3–4 weeks before elective spine surgery. Preoperative weight loss programs to reach a goal BMI <35 kg/m^2 may be a viable solution to minimize wound complications and surgical site infections. To minimize the negative impact of cardiopulmonary comorbidities, patients can enroll in an exercise program prior to surgery. Patients should abstain from alcohol before elective spine surgery. Patients with osteoporosis may benefit from supplementation with Vitamin D, calcium, and parathyroid hormone. Opioids should be weaned to complete cessation 6–8 weeks before surgery. Preoperative cognitive behavioral therapy (CBT) and education seem to be the most beneficial in reducing complications associated with psychiatric comorbidities. Patients should engage in a comprehensive prehabilitation regimen.

Conclusion: Targeting patient risk factors with personalized interventions can improve postoperative outcomes in patients undergoing elective spine surgery.

Keywords: Elective spine surgery, postoperative complications, prehabilitation, preoperative risk

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INTRODUCTION

Elective spine surgeries have increased over the past few decades.[1] To emphasize a focus on value-based healthcare, decreasing postoperative complications remains a priority. Postoperative complications occur in 16%–53% of cases,[1] resulting in increased length of stay (LOS), healthcare costs, readmission rates, and pain.[2] Longer hospital stays burden the patient and the entire healthcare system.[3]

There exist many modifiable risk factors affecting postoperative complications in spine surgery, including drug use, mental illness, elevated body mass index (BMI), and poor nutritional status.[4-8] As such, there has been an increased interest

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in prehabilitation to optimize preoperative risk factors.[9] Prehabilitation is a comprehensive preoperative process used to reduce perioperative complications; ultimately, the goal is to decrease the patient's pain, postoperative disability, and LOS.[10,11] A few studies on physical and psychological prehabilitation for patients undergoing elective spine surgery have shown a significant reduction in postoperative complications compared to patients who have not been exposed to these interventions.[11-13] A systematic review was conducted to identify suggestions to mitigate complications and improve the treatment course in patients undergoing spine surgery.

METHODS

A systematic review was performed using the Preferred Reporting Items for Systematic Reviews and Meta-Analysis guidelines by searching three electronic databases (PubMed, OVID, and Google Scholar) from 1997 to 2021.[14] It sought to identify articles that addressed prehabilitation for known risk factors in spine surgery. The databases were searched for the following keywords: "preoperative risk management," "prehabilitation," "preoperative," and "spine." No language restrictions were applied. This review was not registered *a priori*. The references for all included studies were manually cross-checked to avoid missing relevant studies. Data derived from unpublished studies, presentations, abstracts, or non-peer-reviewed publications were not included. Figure 1 illustrates the method by which articles were identified for further study.

Duplicates were removed after the initial search. One author (P. G.) screened the title and abstracts independently, while a second reviewer (L. M. E.) verified accuracy. Disagreements were resolved through discussion. All nonhuman studies were excluded. Studies were included if they measured the effects of prehabilitation strategies on postoperative outcomes and offered information on prehabilitative strategies generalizable to spine surgery. Studies were excluded if they focused on pediatric populations or prehabilitative strategies used in patients with cancer.

Data extraction

Data were mined independently by one author (P.G.) and were verified by coauthors (N. Agarwal, L.M.E.). Based on reporting prevalence and relevance to patients undergoing spine surgery, data were collected on the following modifiable risk factors: smoking, alcohol, anxiety and depression, anemia, diabetes, osteoporosis, obesity, nutritional status, and opioid use. The level of evidence was also determined using previously described methodology.[15]

RESULTS

The search strategy identified 492 references after removing duplicates [Figure 1]. A total of 178 manuscripts underwent full-text review after which 108 articles were excluded. The search yielded 70 articles eligible for further discussion [Figure 1]. Table 1 provides the level of evidence for each of the included articles. Table 2 summarizes the recommendations provided by the literature and incorporates the authors' best practices with regard to prehabilitation of a patient undergoing spine surgery.

DISCUSSION

The systematic review identified several prehabilitative strategies aimed at improving outcomes after spine surgery. These strategies targeted certain modifiable risk factors, which are presented in further detail in the upcoming sections.

Smoking

Smoking contributes to impaired wound healing and a higher occurrence of wound infections by altering fibroblast activity and decreasing angiogenesis.[4,12,16,58] Studies have also highlighted the negative impact of smoking on vertebral bone and disc matrix proteoglycans, leading to disc degeneration and loss of vertebral body mass.[58] For this reason, smoking can lead to an increase in pseudarthrosis in most lumbar spine procedures.[17,59]

Preoperative smoking cessation can alleviate or reduce surgical site infection (SSI) rates and increase wound healing. Mills *et al*. showed an overall 41% risk reduction in postoperative complications (i.e., wound, pulmonary, and total complications) in patients who quit 4 weeks before surgery, across several specialties.[18] With respect to spine surgery, Ward *et al*. examined the potential impact of prior smoking cessation on postoperative lumbar spine degeneration and identified a potential reversible effect.[17] Comparatively, some studies showed no significant change in postoperative complications immediately following smoking cessation; however, it is still specified, and preferred, that cessation occur due to the potential impact of smoking on bone health.[19]

A retrospective study of 188 patients by Kuri *et al*. assessed wound healing at different levels of preoperative smoking cessation among patients undergoing head and neck surgery.[20] The authors determined that smoking cessation, initiated for longer than 3-week preoperatively, alleviated some impairments in wound healing. Several other studies confer that smoking cessation 3–4 weeks before surgical intervention is associated with a significant decrease in postoperative complications such as wound healing,

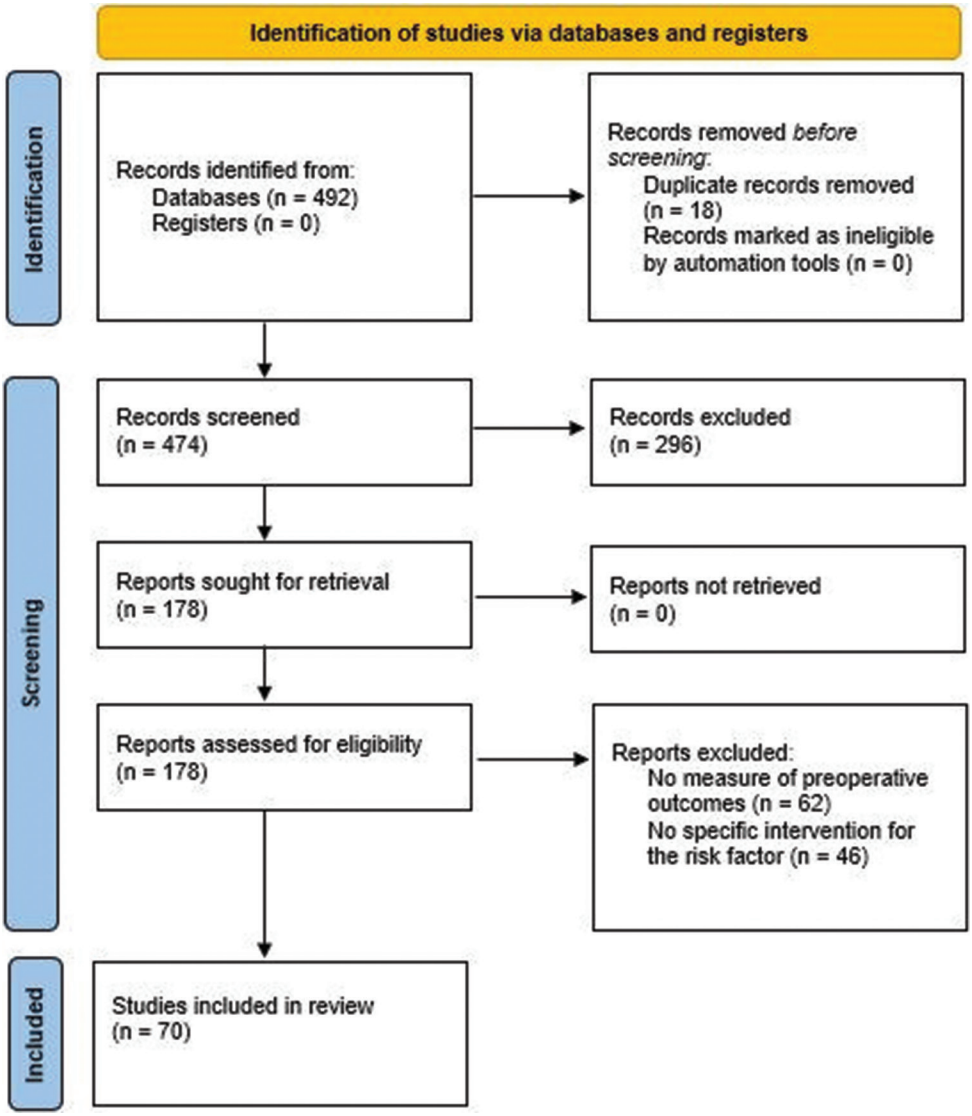

Figure 1: PRISMA flow diagram demonstrating selection of studies for review

longer LOS, and morbidity rates.[20,21,59] Møller *et al*. found that cessation 6–8 weeks prior decreased postoperative morbidity.[22] Furthermore, smoking cessation before surgical intervention increases the likelihood that the individuals will abstain from smoking postoperatively, thereby reducing healing complications.[59]

Nutrition

Malnutrition, as defined by nutritional screening tools such as the Malnutrition Screening Tool (MST), has been linked to increased morbidity, mortality, LOS, readmission rates, and costs following spine surgery.[60] High BMI and malnutrition are typically comorbid with diabetes and metabolic disorders. For this reason, it is difficult to categorize them as independent preoperative risk factors in elective spine surgery.[61] Studies have demonstrated that malnutrition and elevated BMI are associated with increased postoperative infection rates following spine surgery.[60,61] Albumin is a standard marker for malnutrition related to protein deficiencies. Hypoalbuminemia portends poor postoperative outcomes.[23] Recent studies have demonstrated that prealbumin is a biomarker for malnutrition in patients undergoing elective spine surgery.[24] Prealbumin levels of <20 mg/dl are associated with increased postoperative infection rates.[24] Several recommendations have been presented in the literature, however, they cater to a specific population based on BMI, comorbidities, and dietary habits. Furthermore, it is important to consider the relationship between malnutrition and frailty, which has also been linked to postoperative complications in patients undergoing spine surgery. Ultimately, a tailored, patient-specific diet should be provided to the patient before surgery,[25] to mitigate this risk factor.[26]

Table 1: Level of evidence

Authors	Study title	Level of evidence
Zhang and Li, 2018[4]	Risk factors for surgical site infection following lumbar spinal surgery: A meta-analysis	IV
Tønnesen *et al*., 2009[16]	Smoking and alcohol intervention before surgery: Evidence for best practice	II*
Ward and Klesges, 2001[17]	A meta-analysis of the effects of cigarette smoking on bone mineral density	IV**
Mills *et al*., 2011[18]	Smoking cessation reduces postoperative complications: A systematic review and meta-analysis	I
De la Garza Ramos *et al*., 2017[19]	Impact of smoking on 30-day morbidity and mortality in adult spinal deformity surgery	IV
Kuri *et al*., 2005[20]	Determination of the duration of preoperative smoking cessation to improve wound healing after head and neck surgery	IV
Wong *et al*., 2012[21]	Short-term preoperative smoking cessation and postoperative complications: a systematic review and meta-analysis	I
Møller *et al*., 2002[22]	Effect of preoperative smoking intervention on postoperative complications: a randomized clinical trial	II
Gibbs *et al*., 1999[23]	Preoperative serum albumin level as a predictor of operative mortality and morbidity: Results from the national VA surgical risk study	IV
Salvetti *et al*., 2018[24]	Low preoperative serum prealbumin levels and the postoperative surgical site infection risk in elective spine surgery: A consecutive series	IV
Braga *et al*., 2002[25]	Nutritional approach in malnourished surgical patients: A prospective randomized study	II
Fei *et al*., 2016[26]	Risk factors for surgical site infection after spinal surgery: A meta-analysis	IV**
Sing *et al*., 2016[27]	Obesity is an independent risk factor of early complications after revision spine surgery	IV
Narain *et al*., 2018[28]	Is body mass index a risk factor for revision procedures after minimally invasive transforaminal lumbar interbody fusion?	IV
Knutsson *et al*., 2013[29]	Obesity is associated with inferior results after surgery for lumbar spinal stenosis: A study of 2633 patients from the Swedish spine register	IV
Passias *et al*., 2018[30]	Prior bariatric surgery lowers complication rates following spine surgery in obese patients	IV
Giordano and Victorzon, 2014[31]	The impact of preoperative weight loss before laparoscopic gastric bypass	IV
Santo *et al*., 2014[32]	Preoperative weight loss in super-obese patients: Study of the rate of weight loss and its effects on surgical morbidity	IV
Phan *et al*., 2017[33]	Impact of preoperative anemia on outcomes in adults undergoing elective posterior cervical fusion	IV
Seicean *et al*., 2013[34]	Preoperative anemia and perioperative outcomes in patients who undergo elective spine surgery	IV
Ryan *et al*., 2019[35]	Preoperative hemoglobin predicts postoperative transfusion despite antifibrinolytics during total knee arthroplasty	IV
Janssen *et al*., 2021[36]	Intravenous iron in a prehabilitation program for older surgical patients: Prospective cohort study	IV
Theusinger *et al*., 2007[37]	Treatment of iron deficiency anemia in orthopedic surgery with intravenous iron: Efficacy and limits: A prospective study	IV
Di Capua *et al*., 2018[3]	Diabetes mellitus as a risk factor for acute postoperative complications following elective adult spinal deformity surgery	IV
Browne *et al*., 2007[38]	Diabetes and early postoperative outcomes following lumbar fusion	IV
Guzman *et al*., 2014[39]	The impact of diabetes mellitus on patients undergoing degenerative cervical spine surgery	IV
Lee *et al*., 2016[40]	Fat thickness as a risk factor for infection in lumbar spine surgery	IV
Han *et al*., 2021[41]	Alcohol abuse and alcohol withdrawal are associated with adverse perioperative outcomes following elective spine fusion surgery	IV
Elsamadicy *et al*., 2017[42]	Impact of alcohol use on 30-day complication and readmission rates after elective spinal fusion ($\geq$2 levels) for adult spine deformity: A single institutional study of 1,010 patients	IV
Tonnesen *et al*., 1999[43]	Effect of preoperative abstinence on poor postoperative outcome in alcohol misusers: Randomized controlled trial	II
Tempel *et al*., 2015[44]	Impaired bone mineral density as a predictor of graft subsidence following minimally invasive transpsoas lateral lumbar interbody fusion	IV
Tang *et al*., 2007[45]	Use of calcium or calcium in combination with Vitamin D supplementation to prevent fractures and bone loss in people aged 50 years and older: A meta-analysis	I
Heijckmann *et al*., 2002[46]	Intravenous pamidronate compared with oral alendronate for the treatment of postmenopausal osteoporosis	IV
Yerneni *et al*., 2020[47]	Preoperative opioid use and clinical outcomes in spine surgery: A systematic review	III
Jain *et al*., 2018[48]	Preoperative chronic opioid therapy: A risk factor for complications, readmission, continued opioid use and increased costs after one- and two-level posterior lumbar fusion	IV
Hassamal *et al*., 2016[49]	A preoperative interdisciplinary biopsychosocial opioid reduction program in patients on chronic opioid analgesia prior to spine surgery: A preliminary report and case series	VI
Celestin *et al*., 2009[50]	Pretreatment psychosocial variables as predictors of outcomes following lumbar surgery and spinal cord stimulation: A systematic review and literature synthesis	III
Strøm *et al*., 2018[51]	Anxiety and depression in spine surgery—a systematic integrative review	V

Contd...

Table 1: Contd...

Authors	Study title	Level of evidence
Rolving *et al*., 2016[52]	Preoperative cognitive-behavioral intervention improves in-hospital mobilization and analgesic use for lumbar spinal fusion patients	II
Sinikallio *et al*., 2009[53]	Depressive burden in the preoperative and early recovery phase predicts poorer surgery outcome among lumbar spinal stenosis patients: A 1-year prospective follow-up study	IV
Nielsen *et al*., 2010[9]	Prehabilitation and early rehabilitation after spinal surgery: Randomized clinical trial	II
Lindbäck *et al*., 2018[54]	PREPARE: Presurgery physiotherapy for patients with degenerative lumbar spine disorder: A randomized controlled trial	II
Chuang *et al*., 2016[55]	The effect of an integrated education model on anxiety and uncertainty in patients undergoing cervical disc herniation surgery	III
Merrill *et al*., 2018[56]	Impact of depression on patient-reported outcome measures after lumbar spine decompression	IV
Baldini *et al*., 2012[6]	A review of potential adverse effects of long-term opioid therapy: A practitioner's guide	V
Gometz *et al*., 2018[10]	The effectiveness of prehabilitation (Prehab) in both functional and economic outcomes following spinal surgery: A systematic review	I
Koutsoumbelis *et al*., 2011[8]	Risk factors for postoperative infection following posterior lumbar instrumented arthrodesis	IV
Wimmer *et al*., 1998[7]	Predisposing factors for infection in spine surgery: A survey of 850 spinal procedures	IV
Liu *et al*., 2018[57]	Risk factors for surgical site infection after posterior lumbar spinal surgery	IV
Puvanesarajah *et al*., 2016[5]	Risk factors for revision surgery following primary adult spinal deformity surgery in patients 65 years and older	IV

*Meta-analysis but no systematic design, **No trials included. The table excludes basic science and narrative review articles because the scoring system used in the study did not assign a level of evidence to these types of articles

Body mass index

A BMI over 35 kg/m^2 is associated with increased morbidity, longer LOS, and increased wound complications.[4,27,28] Knuttson *et al*. also found that obesity was linked to higher dissatisfaction rates in patients after lumbar spinal surgery.[29] Furthermore, a BMI of over 35 kg/m^2 is directly correlated with a risk of early complications in spinal revision surgery.[27]

For patients with high BMI, bariatric surgery, nutritional plans, and weight loss programs are strongly recommended. Bariatric surgery before spine surgery has demonstrated a lower rate of postoperative complications for morbidly obese patients.[30] Preoperative weight loss programs have shown similar results. Giordano and Victorzon showed that a preoperative weight loss of at least 10% was enough to decrease long-term postoperative complications.[31] One combined program specified 14 weeks of five balanced, nutrient-rich meals combined with indoor/outdoor activities, workshops with occupational therapists, and regular meetings with dieticians. Overall, patients who adhered to the program had fewer postoperative complications compared with those who did not.[32]

Preoperative anemia

Preoperative anemia has been associated with an increased risk of death, blood transfusion, reoperation, unplanned readmission, and extended LOS following spine surgery.[33,34] Hemoglobin levels <13 g/dl for men and <12 g/dl in women have been directly associated with the aforementioned negative outcomes.[35]

Typical preoperative management of anemia involves the administration of intravenous iron for 10 days.[36] This has been shown to improve postoperative outcomes and decrease the need for perioperative blood transfusions in patients undergoing abdominal surgery.[36] Optimal IV iron administration was described as administration 2–3 weeks before orthopedic surgery in trials among patients with a hemoglobin between 10–13 g/dl.[37] Antifibrinolytics have also been linked to a reduction in the need for transfusions perioperatively.[35] At this time, there is not enough evidence to compare the need for intervention in patients depending on surgical type. Overall, patient circumstances need to be considered and further studies need to be done to address the utility of preoperative iron administration.

Diabetes

Diabetes is a demonstrated risk factor for prolonged surgical time and increased rates/risk of infection among patients undergoing lumbar spine surgery.[4,7,38,57,62] Browne *et al*. also showed that diabetic patients who underwent lumbar spine fusion surgery endured longer LOS and incurred more charges than nondiabetic patients.[38] Diabetes, like many other preoperative risk factors, is implicated in several diseases and conditions, such as microvascular disease and cardiac complications. Di Capua *et al*. found that diabetic patients have a 2–4-fold increase in postoperative cardiovascular disease.[3] The authors suggest that an HbA1C < 7 is ideal for preoperative optimization; levels beyond this may predispose to postoperative complications such as SSI. Other complications associated with diabetes include urinary tract infections, metabolic conditions,

Table 2: Prehabilitation recommendations for spine surgery, as per the main takeaways from the literature review and the authors' clinical practice

Preoperative risk factor	Known adverse effects in patients undergoing spine surgery	Testing for risk factor	Recommendation	Confirmatory prior to surgery
Smoking	Increased risk for SSI, impaired wound healing, disc degeneration, and loss of vertebral body mass	Past social history, obtain nicotine level History of patient use of nicotine patch	Advise patient to stop smoking 3–4 weeks prior to surgical intervention	Obtain nicotine level
Opioid Use	Increased length of hospital stay, increased healthcare expenses, higher risks for wound complications, and decrease in mental health	Past social history Check PDMP Check UDS	Wean patients off opioids 6–8 weeks before elective spine surgery, while simultaneously engaging in pain management and CBT. Patient can be placed on a suboxone regimen	Check UDS Check suboxone levels
Obesity	Increased risk for SSI, longer hospital stay, longer operative time, and increased need for revision surgeries	Check BMI when evaluating for elective surgery	Start an inpatient weight loss program until a BMI of<35 is reached. Refer the patient for a bariatric surgery consult	Continue to trend weight loss until it is adequate for risk reduction in surgery
Anxiety and Depression	Longer recovery times, altered anesthesia effects, and decreased postoperative physical improvement	Past psychiatric history PHQ-9/GAD-4 Perform a psychiatric evaluation	Provide proper education of the surgical procedure, accompanied with CBT 1 week preoperatively	Repeat psychiatric questionnaires Repeat psychiatric evaluation
Osteoporosis	Increased risk of vertebral fractures and difficulty with instrumentation during surgery	DEXA scan for all postmenopausal women >65 years, men over 70 years, those with BMI <20–25 kg/m^2, those with oral corticosteroid use, low calcium intake, and for those with a recent history of increased weight loss	Use a multivariable approach in prehabilitation, which includes a primary care physician, nutritionist, endocrinologist, and surgeon to determine the best-individualized treatment plan for osteoporosis Prescribe 1200 mg of calcium supplements for individuals >65 years. Consider calcitonin, Vitamin D, and bisphosphonate therapy	DEXA scan Check calcium and Vitamin D Check renal function tests
Nutrition	Increased mortality rate, infections, complications, and length of hospital stay	Obtain CBC, CMP Perform a review of systems Check prealbumin	Develop patient-specific nutritional plan in an outpatient setting	Recheck pre-albumin and BMI (goal is >20) Check electrolyte levels Look for clinical signs of vitamin deficiency
Alcohol	Multi-organ dysfunction	Blood alcohol levels Past social history	Promote alcohol abstinence one month prior to surgery and start the patient on an outpatient rehabiltation program	Check BACs Check PEth levels
Anemia	Increased mortality rates, reoperation, and extended recovery times	Check hemoglobin and hematocrit Perform iron studies 15 days prior to surgery	Administer IV iron and iron supplements 10 days before surgery. Repeat hemoglobin and hematocrit	Repeat iron studies Trend hemoglobin and hematocrit
Diabetes	Increased length of hospital stay, risk for UTIs, increased risk of cardiac complications, and poor physical recovery	Check HbA1c Monitor blood glucose 4–6 h before surgery	Monitor patient blood glucose levels before surgery (every 4–6 h), avoid administration of regular insulin at a frequency greater than every 6 h, and restrict the patient's carbohydrate intake. Place the patient on a trial of different insulin regimens to find the best option for glycemic control and document the glucose values using a blood sugar log	Repeat HbA1c Monitor blood sugar prior to surgery

BACs - Blood alcohol concentrations; PEth - Phosphatidylethanol; PHQ - Patient Health Questionnaire; GAD - Generalized anxiety disorder; HbA1c - Glycated hemoglobin; UTI - urinary tract infection; BMI - Body mass index; DEXA - Dual energy x-ray absorptiometry; UDS - Urine drug screen; CBC - Complete blood count; CMP- Complete metabolic panel; CBT - Cognitive behavioral therapy; PDMP - Prescription drug monitoring program; SSI - Surgical site infection

immunosuppression, wound infection, mortality, and pseudarthrosis.[3,4,39] There exists a lack of clear consensus as to the appropriate HbA1C cutoffs, given that studies in this area are constructed using large national databases, lacking granular data points such as HbA1C values.[3,38,39] Further study is needed in this area.

There is extensive literature about preoperative planning for patients with diabetes. While these plans are not specific to spine surgery, they can be used to guide clinical decision-making and decrease complications.[63] The preoperative guidelines suggested by Sudhakaran and Surani for patients with diabetes included monitoring blood glucose levels before surgery (every 4–6 h), avoiding the administration of regular insulin at a frequency > every 6 h, and discontinuing antidiabetics.[63] Carbohydrate restrictions can aid glycemic control before surgery and have been shown to reduce postoperative complications.[64,65] Ideally, a diet that consists of 200 g of carbohydrates is recommended for proper nutrition and glycemic management preoperatively.[65] While the recommendation for optimal glycemic control before surgery seems appropriate, further studies are required to clarify its role specific to spine surgery.

Alcohol

The current literature has conflicting results on alcohol's effect on patients undergoing spine surgery. Han *et al*. conducted a multivariable analysis on the impact of alcohol abuse (AA) and withdrawal (AW) on spinal fusion surgery.[41] They showed that patients with AA had longer LOS, total costs, and multiorgan complications.[41] Patients with AW also had an increased risk for multiorgan complications, venous thromboembolism, and wound-related complications.[16,41] However, Elsamadicy *et al*. showed no significant difference in 30-day complication rates and readmission rates between alcoholic and nonalcoholic patients undergoing elective spinal fusion surgery.[42]

Alcohol abstinence has been identified as an important prehabilitation target in the current literature. However, there is a lack of data regarding the role of decreased alcohol intake for patients undergoing spine surgery.[66,67] When this review was conducted, there was only one randomized controlled trial evaluating preoperative alcohol abstinence and its effect on surgical outcomes. Tonnesen *et al*. showed that, following 1 month of abstinence, there was a decrease in patient postoperative mortality, cardiac complications, and response to surgical stress.[43] Several surgeons have used a "brief alcohol intervention plan."[16,43,66] The intervention was conducted specifically on patients undergoing GI surgery; however, the results can be extrapolated to patients undergoing elective spine surgery. Further studies on alcohol abstinence are required to elucidate its role in spine surgery. These studies can also help determine the length of abstinence required for optimal results.

Bone health

Osteoporosis is a significant risk factor for spine surgery. While a T-score of <-2.5 defines osteoporosis, several studies have indicated poor spinal surgery outcomes in patients with T-scores < -1.[68] For example, Tempel *et al*. found that patients with T-scores < -1 were more likely to experience graft subsidence following lateral lumbar interbody fusion.[44] This demonstrates a potential correlation between bone health and spine surgery complication profiles. It should be noted, however, that these T-scores are indicative of the central DEXA test and may not be as representative as femoral T-score values. Many other studies have shown that osteoporosis and poor bone health are linked to negative bone remodeling, increased nonunion amongst fractures, and difficulty with instrumentation, which are all of particular concern in the elderly, where osteoporosis is more prevalent.[69] A major perioperative complication is the difficulty in obtaining proper fixation.[69] Furthermore, an increased risk of fragility fractures and spinal deformities is also seen postoperatively in people with osteoporosis.[70]

For prehabilitative management of poor bone health, it is recommended to use a multidisciplinary approach that includes a primary care physician, nutritionist, endocrinologist, and surgeon to determine an optimal individualized treatment plan.[70] The goal is to optimize bone quality prior to surgical intervention. Smoking has adverse effects on bone remodeling; therefore, cessation of both smoking and anti-inflammatory medications can help reduce postoperative complications.[70] Furthermore, 1200 mg of calcium supplements have been correlated with a reduction in vertebral bone loss in elderly patients over 65 years.[45] Estrogen has also been shown to decrease vertebral fractures by 50% while preventing bone loss.[71] Bisphosphonates have been shown to mitigate high turnover of osteoporosis if administered 6 weeks prior orally or 3 days prior intravenously.[46,72] Lehman *et al.* conducted a literature review for preoperative management of osteoporosis in spine surgery and determined that the most effective prehabilitation treatment included consultation by primary care and endocrine physicians. Thus, a multimodal approach should be taken to determine the best course of treatment for each patient.[70] Calcium, Vitamin D, bisphosphonates, and hormone replacements are among some of the agents used to augment bone density.[70] Specific recommendations for medication optimization in osteoporosis include Vitamin D supplements of 800–1000 IU, of unknown duration, before surgery. Twenty micrograms of subcutaneous PTH have also been shown to improve the risk of osteoporosis in many patients, with no confirmed duration.[45,73] Further research into optimal dosing regimens, for various therapeutics, is required.

Opioid use

Opioids, the most prescribed medication for back pain,

have several associated adverse effects.[6,47,74] Preoperative opioid use in spine surgery, is associated with an increased probability of postoperative opioid abuse, longer LOS, and increased healthcare-associated costs.[47] Other studies have also indicated a correlation between preoperative opioid usage and increased risk of wound complications and readmission.[48]

The management of preoperative opioid use is complex due to patient withdrawal. Hassamal *et al*. studied the effectiveness of a program to reduce preoperative opioid use before spine surgery.[49] The program requires patients to be tapered off opioid medications over 6–8 weeks. The patients simultaneously engaged in physical therapy, occupational therapy, pain-focused cognitive behavioral therapy (CBT), and mindfulness therapy techniques. Preoperative and postoperative improvements in the depression, anxiety, and fatigue domains within the Patient-Reported Outcomes Measurement Information System (PROMIS) used were observed among all patients. Patients also experienced improvements in their pain scores.[49] Further investigation may be required to understand how preoperative opioid weaning can impact hospital LOS and reason for stay.

Psychiatric comorbidities

Psychiatric comorbidities may affect postoperative recovery and complications after spinal surgery. Both depression and anxiety have been associated with longer recovery times, decreased postoperative physical improvement, and overall unfavorable outcomes.[50-53,75] In a study conducted by Merrill *et al*., patients were asked to fill out PROMIS physical function, pain, depression, and anxiety questionnaires before and after lumbar spine surgery.[56] Patients diagnosed with depression demonstrated increased scores for pain and decreased scores from physical recovery compared to those without depression when undergoing lumbar spine surgery.[56] Further, anxiety has been correlated to altered patient response to anesthesia resulting in prolonged extubation and recovery.[76]

Preoperative anxiety may be exacerbated and increased by factors under the control of physicians and healthcare teams. Most patients experience anxiety before surgery, and a lack of information regarding a surgical process contributes to worsened anxiety.[55] Providing patients with proper educational support on their procedures before surgery is associated with a decreased need for anxiety interventions. Ideally, education should be provided directly by surgeons and anesthesiologists.[55] Long-term patient–nurse relationships can also reduce preoperative anxiety.[76] CBT can also decrease preoperative anxiety.[51] Of note, one study showed that participation in preoperative CBT helped facilitate increased mobility in walking, getting up from a chair, and movement from the bed, 3 days after lumbar spine surgery.[52] It is important to note that CBT has also been effective in reducing analgesic consumption and pain scores in patients who underwent spinal fusion without any psychiatric comorbidities.[52] There may be a benefit to allowing all patients to undergo CBT before surgical intervention.[52] Overall, these findings suggest that providing patients with additional information regarding their surgery can help improve postoperative outcomes. Further studies are needed to determine the impact of the previously mentioned interventions and anesthetic complications.

Current interventions

Prehabilitation is a rapidly growing concept in surgery. Thus far, success has been demonstrated in two major randomized clinical trials. Lindbäck *et al*. developed a prehabilitative program labeled PREPARE.[54] It focuses both on improving physical and mental health before surgery. Patients who participated had a statistically significant decrease in pain, increased physical activity, and better psychological well-being before surgery.[54] After surgery, patients in this program had increased activity levels compared to their counterparts, with all other factors remaining comparable.[54] Another study by Nielsen *et al*. focused on delivering a 2-month prehabilitative program before elective spine surgery.[9] Patients in the prehabilitation group engaged in exercise and healthy lifestyle habits, including smoking and drinking cessation. The patients and their families were also required to meet with physiotherapists multiple times for education focused on their spine pathology and surgery. Patients who went through the program had significantly reduced hospital stay and greater satisfaction after spine surgery.[9] Ultimately, further studies and trials are needed to optimize patient prehabilitation processes.

There is still a lack of implementation of prehabilitation programs within spine surgery in the United States. This is likely multifactorial but may be due to a lack of awareness surrounding the prehabilitation process and its benefits. One possible way to increase interest is to have a preset model for prehabilitation at an institutional level to help guide physicians through a prehabilitation process.[77] Figure 2 illustrates a compilation of the perioperative risk factors discussed previously and serves as a foundation for the Prehabilitation Model. Most importantly, it must be remembered that prehabilitation varies according to the patient, their pathology, and the nature of the surgery (i.e. decompression, instrumentation and fixation, minimally invasive, open). One such example of this is with BMI and lumbar spondylolisthesis. Contrary to what has been shown to be a safe BMI in the presented literature review, recent evidence from Agarwal *et al*. demonstrated that a BMI

of up to 37.5 kg/m^2 is amenable to satisfactory patient and surgical outcomes following the management of low-grade lumbar spondylolisthesis.[78] This leniency in threshold may be attributed to a growing confidence in performing complex spine surgery over time. Regardless, it calls to action a greater inquisition into the prehabilitation principles for spine surgery. Improving physician and patient awareness in this field can help encourage the mobilization of stakeholders toward these initiatives.

Limitations

Qualitative data were mainly extracted. The search patterns utilized may have excluded pertinent literature. Extraction of granular data points, allowing for meta-analysis, should be pursued in the future. Finally, further study into the clinical utility of all the suggestions is warranted.

CONCLUSION

The use of prehabilitation before surgery can decrease postoperative complications and morbidity. This literature review identified the complications that can be incurred if risk factors are not optimized before elective spine surgery. Individualized preoperative interventions aimed at these factors can help decrease wound infection, postoperative morbidity and pain, LOS, and hospital-associated costs. The next steps in the implementation of prehabilitation require the clinical testing of the recommendations listed above to optimize timelines and doses for many of the interventions, including cessation or elimination of drugs, alcohol, and tobacco use. With advanced clinical testing, prehabilitation may soon become standard practice in spine surgery.

Figure 2: Artistic depiction of the modifiable risk factors in elective spine surgery

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Conflicts of interest

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