Curr Rev Musculoskelet Med (2016) 9:316–326
DOI 10.1007/s12178-016-9351-x

Complication avoidance with pre-operative screening: insights from the Seattle spine team

Quinlan D. Buchlak[1] **· Vijay Yanamadala**[1] **· Jean-Christophe Leveque**[1] **·**
Rajiv Sethi[1,2]

Published online: 3 June 2016

Abstract Complication rates for complex adult lumbar scoliosis surgery are unacceptably high. Standardized preoperative evaluation protocols have been shown to significantly reduce the likelihood of a spectrum of negative outcomes associated with complex adult lumbar scoliosis surgery. To increase patient safety and reduce complication risk, an entire medical and surgical team should work together to care for adult lumbar scoliosis patients. This article describes preoperative patient evaluation strategies with a particular focus on adult lumbar scoliosis surgery involving six or more levels of spinal fusion. Domains considered include recent preoperative evaluation literature, predictive risk modeling, the appropriate management of medical conditions, and the composition and activities of a multidisciplinary conference review team. An evidence-based comprehensive systematic preoperative surgical evaluation process is described.

Keywords Adult lumbar scoliosis · Spine surgery · Risk mitigation · Risk stratification · Multidisciplinary patient care · Surgical risk management

This article is part of the Topical Collection on *Complications in Spine Surgery*

✉ Rajiv Sethi
rajiv.sethi@virginiamason.org

1 Neuroscience Institute, Virginia Mason Medical Center, Seattle, WA, USA

2 Department of Health Services, University of Washington, Seattle, WA, USA

Introduction

Complication rates in complex adult lumbar scoliosis surgery are high and too often result in unacceptable patient impairment and disability. Complication rates reported for these procedures range from 25 to 80 % [1, 2]. Even for general spine surgery, intraoperative adverse event rates reported in the literature reach 10 % [3–9]. Complex spine surgery, defined as a surgical procedure requiring six or more levels of vertebral fusion, is typically used to correct adult lumbar scoliosis. This type of procedure is a high-risk undertaking and is often quite morbid in nature [10–13].

Surgical complications can be divided into three main categories: (1) intraoperative, (2) short-term (within the first 90 days postoperative), and (3) long-term (greater than 90 days postoperative). Preventable intraoperative complications include severe blood loss, surgeon error or misjudgment, coagulopathy, and hypotension [14•, 15]. Short-term complications include local or systemic infection, thromboembolism, poor wound healing, implant-related problems with neurologic sequelae, postoperative pain requiring reoperation, and complications arising from comorbid conditions. Long-term complications include pseudarthrosis, latent infection, implant fatigue and failure, and proximal and distal junctional failures [16–20].

Our goal in this article is to describe ways to reduce the risk of complications and negative patient outcomes by applying preoperative patient screening methods, with a particular focus on high-risk complex spine surgery to treat adult lumbar scoliosis. Recent literature is reviewed and a comprehensive systematic approach to preoperative patient evaluation and risk management is presented.

Preoperative evaluation literature

A review of the recent literature was conducted. Databases queried included PubMed, Google Scholar, Scopus, and Web of Science. Search terms included "preoperative evaluation," "lumbar spine surgery," "predicting complications," "reducing the risk of complications," and "improving patient safety." Papers included in the review (1) focused on lumbar spine surgery, (2) focused on preoperative patient evaluation, and (3) were published recently (since 2014).

The articles derived from this search were surveyed to identify those that specifically focused on preoperative evaluation in spine surgery and the prediction of postoperative patient outcomes. Akins et al. [21] investigated predictors of 30-day readmission for spine surgery patients. Multivariate analyses of data from 14,939 patients found that the following factors predicted 30-day hospital readmission: presence of malignancy; longer operative time (any operation greater than 200 min in length); longer hospital stay (longer than 6 days); surgical complications (dural tear, infection, epidural hematoma); depression; rheumatoid arthritis; deficiency anemia; and hypothyroidism [21]. Bekelis et al. conducted a retrospective study involving data from 13,660 patients to create a predictive model of spine surgery complications, including 30-day postoperative risk of stroke, myocardial infarction, infection, urinary tract infection (UTI), death, deep vein thrombosis (DVT), pulmonary embolism (PE), and unplanned return to surgery. Their model, based on preoperative patient characteristics, was successfully able to discriminate between cases that did not experience complications and those that independently experienced stroke, death, myocardial infarction, infection, UTI, PE, DVT, a length of stay of 3 days or more, and unplanned return to surgery. Areas under the receiver operating characteristic curves ranged from 0.65 to 0.95 [22•]. Wang et al. conducted a retrospective review to assess the risk of myocardial infarction for patients within 30 days of spine surgery. Multivariate logistic regression analysis suggested that age in excess of 65 years, atrial fibrillation, hypertension, a history of myocardial infarction, the use of anticoagulants, low albumin, a length of stay greater than 7 days, intraoperative blood transfusion, trauma etiology, a baseline creatinine greater than 1 mg/dL, and a procedure involving more than two levels of spinal fusion were each significant independent predictors of an increase in the likelihood of postoperative myocardial infarction [23]. Chitale et al. [25] developed a patient comorbidity score based on a prospective study of complications occurring in cervical and thoracolumbar degenerative spine surgery patients. ICD-9-based modeling and multivariate logistic regression analyses suggested that the score correlated with the occurrence of complications in spine patients and performed as well as the Charlson index [24] in predicting the risk of complications in spine patients. This study suggested that the following factors were associated with the occurrence of complications: neurological deficit, cardiac conditions, and drug or alcohol use [25]. Nerland et al. found that the following factors were associated with patient deterioration after decompressive surgery for single and 2-level lumbar spinal stenosis: smoking, decreasing preoperative Oswestry Disability Index (ODI), previous surgery at the same level, previous surgery at another lumbar level, American Society of Anesthesiologists grade ≥3, and decreasing age [26]. Jiang et al. conducted a systematic review of the literature investigating the effect of obesity on surgical outcomes and complication rates in spine surgery. According to this review, obese patients were significantly more likely to experience a higher revision rate, greater blood loss, venous thromboembolism, longer operative time, and mortality [27]. Buerba et al. conducted a retrospective analysis of prospectively collected data for 10,387 patients undergoing lumbar surgery to investigate the relationship between obesity and complication risk. Obese patients (BMI = 30 to 39.9) had a significantly increased risk of urinary and wound complications. Patients with a BMI of 40 or more experienced significantly increased operative time and extended length of stay and were at significantly greater risk of complications, particularly pulmonary complications [28]. Marquez-Lara et al. conducted an analysis of data from 24, 196 patients who underwent lumbar spine surgery between 2006 and 2011. They found that obesity significantly increased the likelihood of DVT, superficial wound infection, PE, UTI, acute renal failure, and sepsis. There was no significant increase in the risk of 30-day mortality for obese patients according to this study [29]. Salvetti et al. found that preoperative nutritional status (preoperative prealbumin <20) and diabetes were predictors of postoperative infection in spine surgery [30]. As one can see from this survey, a wide range of preoperative and intraoperative conditions are associated with the development of postoperative conditions, potentially making the preoperative selection of the "ideal patient" quite difficult, and a challenging goal in these often older patients with multiple comorbid conditions.

Recent research has also focused on associations involving psychological and psychiatric factors. Ellis et al. conducted a meta-analysis of studies investigating the link between preoperative patient expectations (pain expectations and general expectations) and their functional outcome after lumbar spine surgery. Patient expectations that were more positive prior to surgery were significantly associated with better postoperative functional outcomes [31]. Mendez et al. conducted a study investigating the associations between preoperative diagnoses of psychiatric conditions and postoperative negative outcomes. Psychiatric conditions included anxiety, depression, schizophrenia, and dementia. Postoperative negative outcomes included adverse events, mortality, and non-routine discharge. Results suggested that patients carrying a diagnosis of depression, anxiety, schizophrenia, and dementia were more likely to experience non-routine discharge. These patients were also more likely to experience adverse events and patients with dementia had a higher risk of dying during their hospital stay [32•]. A study by Chapin et al. suggested that patients with depression, patients who were current smokers, and patients on disability benefits at the time of lumbar spine surgery had worse postoperative functional outcomes, as measured by ODI and the European Quality of Life-5 Dimensions (EQ-5D) scores at both 3 and 12 months after surgery. These three factors were also significantly and negatively associated with patient satisfaction after lumbar spine surgery [33]. Vasquez-Castellanos et al. found that after cervical spine surgery, smokers were more likely to experience higher pain scores, lower EQ-5D scores, and lower satisfaction than non-smokers [34].

While these types of analyses can provide an indication of potential independent variables associated with poor postoperative outcomes, studies applying predictive modeling techniques to measure real-time predictions of positive and negative patient outcomes are not common and vary substantially. They differ with regard to study design, predictor variables, outcome variables, and surgical procedures considered. These predictive modeling studies and scales can be especially informative to practitioners engaged in preoperative planning activities and discussions of appropriate patient care. Efforts to develop such predictive models and tools are progressing. One recent example is the SpineSage tool developed by Lee et al., which is designed to assess the risk of complication for an individual patient having spine surgery, based on their preoperative status and planned surgical procedure [35]. Overall, however, the application of predictive models to patient risk stratification and surgical practice in the form of efficient and usable decision support systems appears to be limited at this time. The incorporation of decision support tools based on robust predictive modeling into broader systematic approaches to preoperative patient evaluation is likely to contribute to increasing patient safety.

Comprehensive standardized perioperative protocols

Standardized perioperative protocols significantly reduce the likelihood of many immediate, short- and long-term negative outcomes in complex spine surgery [14•]. These systematic protocols bring together various risk management strategies that are designed to target specific complications individually [16, 36–38]. Joy et al. found that the implementation of a standardized handover protocol significantly reduced the number of technical errors and information omissions that occurred when patients were transitioned from the operating room to intensive care. Additionally, handoff content and perceptions of teamwork were improved, while handoff duration did not change [39].

To increase patient safety and reduce risk, an appropriately trained and dedicated medical team should care for the complex spine patient from their pre-operative state through to their recovery. Expertise from multiple fields and a range of care management processes are required to increase the likelihood of positive patient outcomes and mitigate the risk of complications. The recently published full-spectrum, system-focused Seattle Spine Team Protocol (SSTP) approach to managing adult lumbar scoliosis patients centered on (1) a live multidisciplinary preoperative complex spine conference to assess the appropriateness of surgery on a case-by-case basis and to coordinate care from the preoperative state through to discharge, (2) a collaborative intraoperative surgical team focused on increasing efficiency and mitigating risk through the use of two attending co-surgeons and a specialized complex spine surgery anesthesia team, and (3) the application of a rigorous intraoperative monitoring protocol to assess and treat blood loss and coagulopathy [14•]. This systematic three-pronged approach to risk management comprehensively addresses the standard complication domains described previously. Effective and systematic pre-operative patient evaluation and management forms a core component of full-spectrum surgical risk management protocols and contributes to assessing and mitigating risk, reducing complication rates, and improving patient safety and outcomes [14•].

Medical condition evaluation and management

Given the complicated medical history of many of these older patients being considered for adult deformity surgery, a range of medical specialties should be involved in the preoperative patient evaluation process for complex spine surgery. These clinical groups should include anesthesiologists, orthopedic surgeons, neurosurgeons, neurologists, intensivists, cardiologists, and internists in order to fully address the varied perioperative needs of each patient. An attending complex spine anesthesiologist for each patient should be closely involved early in the patient evaluation process, and we have found that having the anesthesiologist guide the initial discussion of medical concerns prevents the conversation from focusing only on surgical issues. The anesthesiologist provides an early overview of the patient's medical record and proposes any early medical evaluations that may be required prior to clearance for surgery. These evaluations often include pulmonary and cardiac-focused consultations. Once these consultations have been completed, these results form an integral piece of the final decision-making process.

All patients referred to our Seattle surgical spine clinic with a diagnosis of adult lumbar scoliosis undergo a thorough history taking process and a comprehensive physical examination. This first step in the patient review process includes an assessment of the patient's functional status. The patient's mobility is assessed along with their ability to conduct daily living activities. The visual analog score (VAS) is used to assess their pain status and their current pain medication regimen is recorded. Patients are required to complete an EQ-5D questionnaire and an ODI scale. The patient's smoking history is confirmed along with their current smoking status. Current smoking status is recorded by volume and frequency. If a patient is found to be a smoker, surgery is delayed until they cease any nicotine-containing products. This cessation is confirmed with a urine nicotine test 1 week prior to the proposed potential surgery date. The current medication list and any significant comorbidities are also recorded. The cardiac, pulmonary, and hemostatic systems are assessed for potential comorbidities by medical record review and direct questioning [36, 40].

A standard set of preoperative studies are obtained for all patients. These studies include 36 in. (91.4 cm) standing antero-posterior and lateral spine films and a lumbar spine x-ray including flexion-extension views. Magnetic resonance imaging of the lumbar spine is obtained for patients with symptoms of neurogenic claudication or radiculopathy. X-rays and MRI scans are carefully assessed in conjunction with the history and physical examination information to determine whether a patient would be likely to benefit from surgical intervention. Preoperative radiographic evaluation includes measurements of sagittal and coronal balance, pelvic parameters, and Cobb angles of major and minor curves [41]. These measurements, considered in conjunction with the patient's history, suggest potential surgical procedures that are most likely to alleviate the patient's symptoms and improve their functional status. Refinement of the proposed surgical procedure is based on a discussion held between at least two senior surgeons. This discussion typically includes at least one neurosurgeon and at least one orthopedic surgeon. The semi-structured discussion and the resulting refined surgical procedure include consideration of all data and information collected. This discussion results in the formulation of a feasible, effective, safe, and specifically tailored surgical strategy. A computed tomography scan of the spine for instrumentation planning is also typically ordered at this time.

Osteoporosis can substantially impact outcomes associated with complex spine surgery [28], and therefore, an assessment of bone quality is an important consideration in the preoperative evaluation process. All patients receive a preoperative DEXA scan. The *T* score at the femoral neck is the primary bone quality measure taken into account. Since low bone mineral density is significantly associated with proximal junctional kyphosis (PJK) in patients with adult scoliosis [42], any patient classified as being osteopenic (*T* score between −1 and −2.5) is considered for cement augmentation at two locations at the time of surgery: (1) the upper instrumented vertebra (UIV) and (2) the vertebra above the UIV. This technique is controversial in the current spine literature and can be associated with complications related to extrusion of cement, but our experience has mimicked that of the cadaveric and clinical studies demonstrating a decrease in PJK with the use of cement augmentation [43–45]. The team is unlikely to recommend surgery for any patient with a *T* score less than −2.5, except in rare cases of severe decline or neurologic compromise. Osteoporotic patients are referred to endocrinology and are evaluated for treatment with teriparatide by the endocrinology team. Once the endocrinologist has treated the patient, another bone density scan is conducted and the patient's case is re-reviewed by the conference team.

After presentation at the multidisciplinary conference, any further recommendations that arose during the conference discussion are acted upon prior to scheduling the surgical case. Often, patients requiring extensive secondary consultations will be re-presented at a later conference once these consultations have been completed so that the entire team can evaluate the results and potential risk of surgery. Figure 1 links the preoperative medical evaluation processes with the main domains of risk it aims to mitigate.

The multidisciplinary preoperative spine team conference

The SSTP calls for a live, in-person multidisciplinary preoperative evaluation and discussion of all complex spine patients [14•]. This comprehensive multidisciplinary medical review and discussion is aimed at ensuring that patients receive optimal treatment, either surgical or nonoperative management. The conference discussion is focused on the risk of complications and possible steps to mitigate risk should spine surgery be deemed appropriate and beneficial.

Once a patient has been deemed as a potential operative candidate for the correction of a spinal deformity, based on surgical and medical evaluation, their case progresses to the multidisciplinary review conference. These conferences are conducted on a monthly basis and involve representatives from many medical and allied health specialties, including cardiologists, physiatrists, specialized complex spine anesthesiologists, neurologists, intensivists, internists, neurosurgeons, and orthopedic surgeons. Other specialists (e.g., infectious disease physicians) are invited to the conference when a case specifically requires their expertise. Allied health specialists involved in the conferences include physiotherapists, nurses, physician's assistants, and clinical researchers. At least two members of the dedicated complex spine anesthesiology team attended and they play an integral role in the review of each case. The spine clinic nurses who coordinate the preoperative complex spine patient education class also attend.

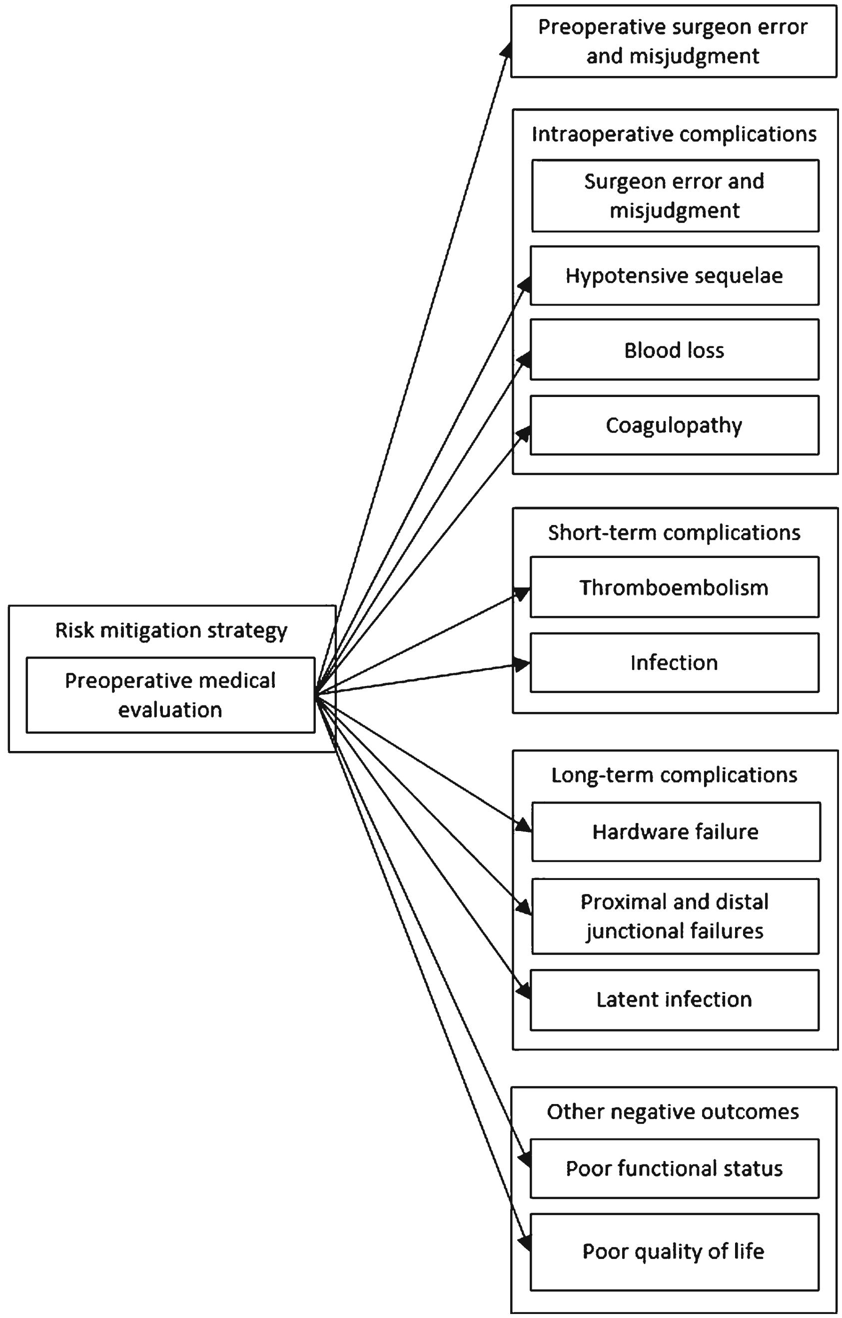

Fig. 1 Risks mitigated by the preoperative medical evaluation processes of the Seattle Spine Team Protocol

The anesthesiologists and an internist review each patient's history and medical issues before the conference. A written summary of the patient's past medical history, their spine clinic evaluation summary note, relevant laboratory values, and screening tests (electrocardiogram, echocardiogram, etc.) is then generated. This is sent to conference participants for review a week prior to the conference.

For each patient, discussion focuses on the proposed surgical correction, the correction process, and the preoperative and postoperative medical issues relevant to the patient. One hallmark of the conference discussion is that both non-surgeon members and surgeon members of the committee have equal power to decide the suitability of each case. The views of all attendees are taken into account and seriously considered. This "equal voice" setup differs from traditional approaches taken at other institutions. Our personal training experience suggests that in most academic institutions and spine surgery practices, surgeons wield the primary decision-making power and can decide to move ahead with surgery without the involvement of other clinicians. In these situations, non-surgeon members of the care team may face difficulties and frustrations, as they are often left to prepare patients preoperatively and care for them postoperatively as best as they can while wondering why a particular patient was selected for surgery in the first place. Differences in training, patient exposure, and experience may result in these stakeholders being more acutely aware than the primary surgeons of important preoperative medical factors that may be critical to informing the accuracy and quality of preoperative decision-making. It is our proposal, therefore, that including their insights in the preoperative evaluation process will contribute to an increase in patient safety and a decrease in the risk of complications. With the increasing specialization of medical care, it is not realistic to expect that a single spine surgeon can fully and effectively manage the risk of the various cardiac, pulmonary, hematologic, and renal complications that may arise in high-risk complex spine surgery.

The SSTP requires that each surgical patient have majority, although not unanimous, support from all interested parties involved in the conference. This requirement means that patients who might appear to be surgically viable based on radiographic imaging, physical examinations, and clinical history can be deemed unsafe for surgery due to concerns raised by non-surgeon members of the conference review team. The developers of the SSTP assert that this focus on separating non-medical surgeon biases, including political or economic incentives, from the decision-making process is critical to ensuring that appropriate and safe decisions are made for every patient.

A substantial proportion of potential complex spine surgery patients are not approved for surgery at their first presentation as a result of the multidisciplinary conference review process. Over the past 5 years, the multidisciplinary medical team involved in the SSTP conference review process came to the decision that approximately 25 % of patients presented at the conference had medical conditions that rendered them unsuitable for the extent of complex surgical treatment being proposed. When this decision occurs, the case may be deferred until further workup is completed. These delayed patients may be exposed to further in-depth evaluation and pretreatment processes based on the conference discussion and are then brought back for re-review at a later date. Alternatively, a nonoperative plan may be pursued for these patients [46].

The result of each patient's conference discussion is summarized and added to their medical record. The primary surgeon discusses the results of the conference review directly with the patient. This discussion facilitates a shared decision-making process, which values and takes into account the concerns, views, and preferences of the patient and their family.

The preoperative multidisciplinary conference is designed to reduce a multitude of potential short- and long-term postoperative complications through appropriate patient selection and preoperative optimization. Figure 2 links the preoperative multidisciplinary conference process with each main domain of risk it is designed to address.

Patient preparation and preoperative optimization

Once a patient has been cleared by the conference and has been deemed eligible for surgery, they enter the next phase of the SSTP. All surgical patients attend a 2-h education class, which is run monthly by clinic nurses and one of the spine surgeons. This class focuses on the postoperative recovery period and involves a question-and-answer session and the distribution of printed materials to foster understanding for the patient and their family. All patients are then engaged in a lengthy informed consent process that includes a discussion of risks. Risks discussed include the likelihood of severe bleeding, infection, proximal junctional kyphosis, implant failure, postoperative neurologic injury, blindness during spine surgery, stroke, and death [4, 47–50]. Clear and efficiently usable risk calculators based on robust data-driven predictive statistical models may be beneficial in informing the surgical risk conversation with the patient. The application of these tools in this way may further foster patient understanding and benefit the informed consent process.

At this point, a more detailed preoperative evaluation is conducted by an internist. Depending on the patient's needs and the conference discussion, further cardiac evaluation may be obtained based on the guidelines of the American College of Cardiology and American Heart Association for perioperative risk stratification [51]. Pulmonary function tests are also obtained if needed [52]. If the patient has normal preoperative coagulation and hematologic panels, four units of packed red blood cells and four units of thawed plasma are crossed and typed. If the evaluation team discovers abnormalities in hematocrit or coagulation, an additional workup is completed involving both hematology and internal medicine.

Members of the acute pain service team evaluate all patients to further assess and review their baseline pain and current pain regimen. This analysis informs the development of a tailored individual perioperative pain regimen. The attending anesthesiologists who supervise the resident and fellow team and direct the pain service are closely involved with the complex spine surgery team. These anesthesiologists are therefore keenly aware of the unique issues that may be faced by this specific patient population and understand the importance of early mobilization and frequent communication with members of the daily rounding primary spine care team.

Figure 3 presents a diagram that synthesizes the entire preoperative evaluation process. This diagram illustrates the process steps and key decision points for (1) preoperative medical evaluation, (2) the multidisciplinary complex spine review conference, and (3) further postconference preoperative evaluation activities. The preoperative evaluation process is multifaceted, systematic, comprehensive, and structured. An opportunity to include the application of model-driven decision support systems in the form of risk calculators is marked.

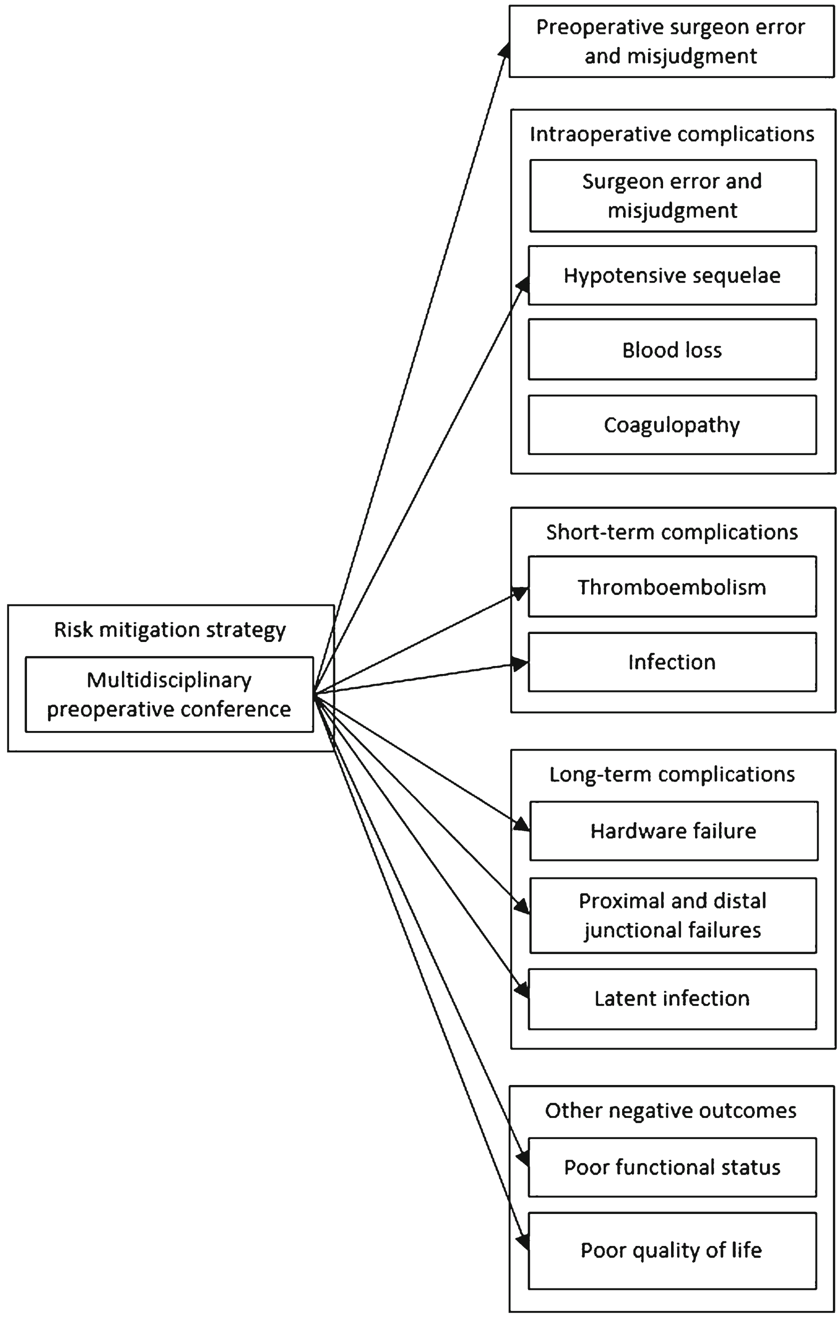

Fig. 2 Risks mitigated by the preoperative multidisciplinary review conference of the Seattle Spine Team Protocol

Risk reduction efficacy

Recently published data suggested that the processes of the SSTP have significantly reduced complication rates, even in an institution where baseline complication rates were lower than published benchmarks [14•]. Outcomes of complex spine surgery patients who were exposed to the full SSTP process were compared to the outcomes of patients who underwent complex spine surgery prior to the implementation of the SSTP. The complication rate in the SSTP group (16 %) was significantly lower than the total complication rate of the non-protocol group (52 %). The SSTP group was less likely to return to the operating room during the postoperative 30-day period (0.8 vs. 12.5 %) and showed significantly lower rates of UTI (9.7 vs. 32.5 %).

Continuous preoperative evaluation protocol improvement

The SSTP is underpinned by the principles of continuous improvement [53–55]. The generation of the highest quality outcomes and safe patient care are the primary goals of the design and application of the SSTP. If care team members and

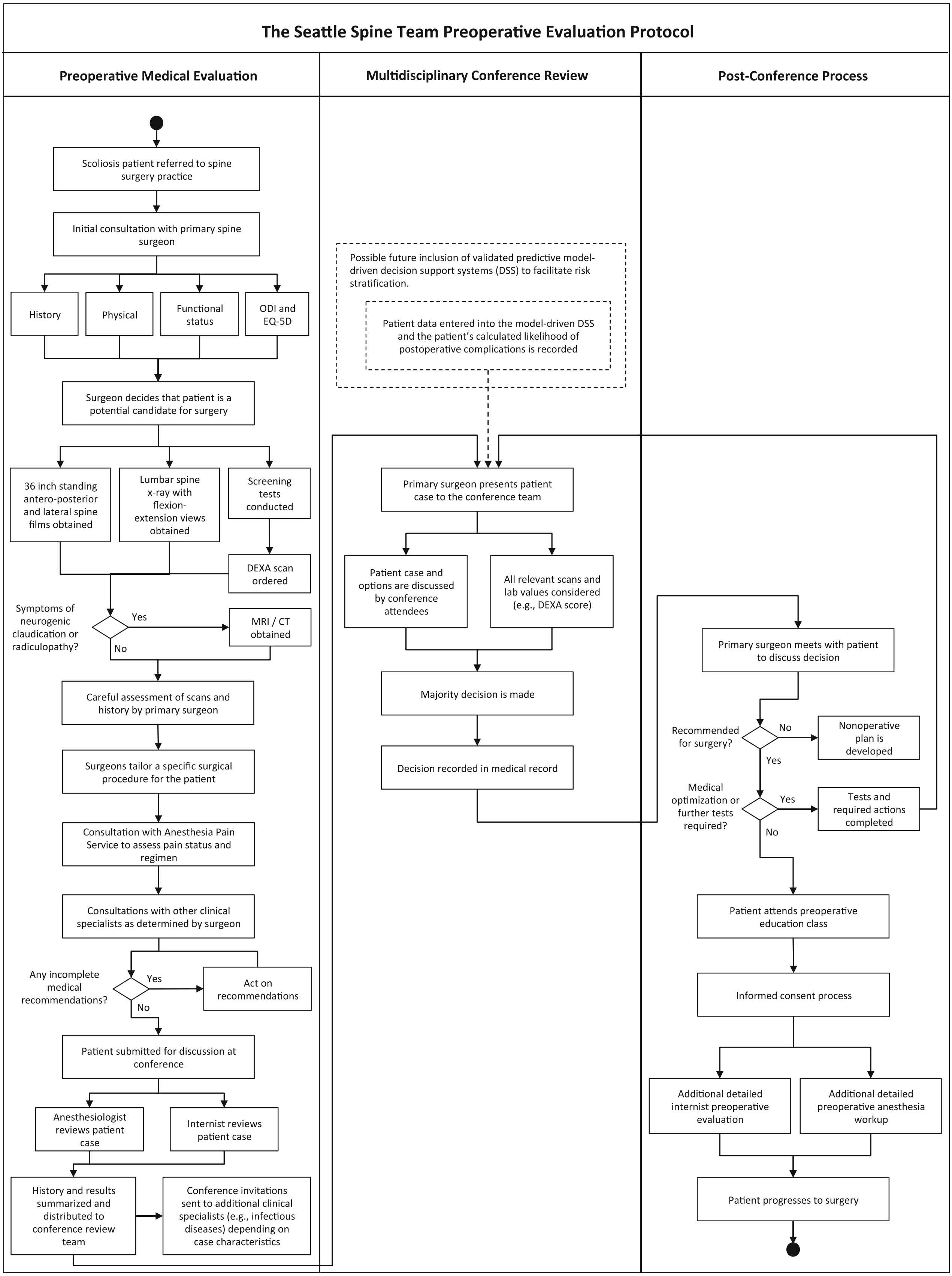

Fig. 3 Activity diagram illustrating the entire preoperative evaluation process and key decision points

researchers identify potential process improvement opportunities, these proposals are discussed, trialed, and implemented. To continue to improve the safety of patients undergoing complex spine surgery, input is actively elicited from all care team members and considered thoughtfully by process improvement decision makers. It is important to continually eliminate inefficiencies in this detailed process and to arrange for the adequate provision of resources by the institution to ensure that the process is timely and thorough. As one example, in early conferences, the non-surgical team members often arrived without having reviewed the patient cases to identify red-flag items. Conference time was therefore being spent inefficiently combing the medical record for specific details. The preconference process was altered so that the list for each conference was circulated 1 week prior to the meeting, with the understanding that surgeons would come prepared to discuss the proposed surgical plan and anesthesiologists and internists would have already reviewed the medical record to discuss potential concerns. At regular points in time, a member of the complex spine surgery team conducts a review that involves purposefully gathering information from stakeholders across the care continuum to identify improvement opportunities. Perioperative data is collected, tracked, and analyzed to generate insights into the efficiency and efficacy of the system. Processes are compared to and informed by the most recent data published in the literature and other examples of best practice. Adjustments are made if needed. Continuous improvement of the SSTP occurs by leveraging the ideas and insights of the broader hospital care team. With the national and global move towards delivering value-based healthcare, proactive strategies aimed at maximizing healthcare quality can attract patients and drive long-term practice success [56].

Conclusion and future directions

Effective preoperative evaluation is critical to mitigating risk and avoiding complications in complex spine surgery, and ensures the provision of appropriate and safe treatment to patients with adult lumbar scoliosis. Thorough multispecialty preoperative evaluation reduces the likelihood of many complications. This process involves comprehensive preoperative medical review, individual consultation with multiple medical specialists, presentation of the patient's case at a live multidisciplinary conference, additional subsequent specialist medical review, and evidence-based proactive continuous improvement. Further predictive modeling research and the application of well-designed decision support systems represent substantial opportunities to further improve the preoperative evaluation process and informed decision-making in high-risk surgical disciplines. A systematic multidisciplinary approach to preoperative evaluation is essential in reducing the risk of complications and maximizing quality and safety in complex spine surgery.

Compliance with ethical standards

Conflict of interest Quinlan D. Buchlak, Vijay Yanamadala, Jean-Christophe Leveque, and Rajiv Sethi declare that they have no conflict of interest.

Human and animal rights and informed consent This article does not contain any studies with human or animal subjects performed by any of the authors.

Disclosures All authors have reviewed and approved this manuscript and have no relevant disclosures to report.

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