Treatment Algorithms and Protocol Practice in High-Risk Spine Surgery

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KEYWORDS

• Evidence-based medicine • High-risk spine protocol • Spine surgery • Spinal deformity

KEY POINTS

- Protocol-based care has been shown to improve outcomes in many care pathways.
- Increasing understanding of surgical goals in spinal deformity surgery as well as improved techniques used to achieve such goals has led to improved outcomes.
- As more patients are considered for surgical intervention, the medical comorbidities and potential complications require thorough and appropriate workup.

INTRODUCTION

The treatment of complex spinal deformity is becoming increasingly more common as the population ages. Pain and difficulty with balance are the leading complaints of elderly (age >60 years) patients undergoing complex spinal reconstruction.[1–3] The focus of treatment for such abnormality is centered on the spinal deformity, but one must pay close attention to the overall medical condition and relevant comorbidities that may complicate the operative course. With improvements in surgical technique and anesthetic management, the surgical ability to tackle complex deformity is increasing, but enthusiasm must be tempered by the medical challenges and the patient's ability to tolerate surgery. Glassman and colleagues[4] have categorized a series of complications as either major or minor. This study reported a 10% rate of major complications in patients undergoing major adult spinal reconstruction, whereas more recent studies have shown a 34.3% rate of major complication including a 19.3% rate of perioperative complications and an 18.7% rate of long-term complications.[5] The risk factors for perioperative complications were advanced age, medical comorbidities, and obesity; however, the only factors that were found to negatively affect patient outcomes as demonstrated on the Scoliosis Research Society questionnaire and the Oswestry Disability Index (ODI) were those found at follow-up, such as presence of a 3-column osteotomy or progressive loss of sagittal correction.[5] In the setting of spinal deformity, the surgeon's goal is to apply various surgical techniques to restore sagittal alignment and safely decompress neurologic structures. The clinical importance and significant patient impact of restoring sagittal alignment has been demonstrated in the literature[6–9]; however, the magnitude of the operation that would be

Disclosures: P.A.S., R.J.H: None. T.R.K: Consultant: Medtronic, Nuvasive, Globus; Research Funding: Medtronic, NIAMS.

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Neurosurg Clin N Am 24 (2013) 219–230
http://dx.doi.org/10.1016/j.nec.2012.12.012
1042-3680/13/$ – see front matter

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required to correct a complex deformity must be one that the patient can tolerate medically.

As much as 68% of the population older than 60 years has been shown to have some form of spinal deformity, and limitation in activity and overall disability are the most powerful factors driving individuals to surgery.[10] The overall complication rate in adult revision spinal surgery has been reported to be as high as 40%, and the factors associated with the highest rate of complication include patient age, medical comorbidities, and extension of fusion to the sacrum.[3,4,11–15] Because of the lack of physiologic reserve and multiple medical comorbidities, the complication rate can be even higher in the elderly population.[2,3] Despite the higher rate of complications, Drazin and colleagues[2] have demonstrated that elderly patients benefit from deformity correction. In fact they demonstrated, for patients with a mean age of 74.2 years, a mean reduction in ODI of 24.1 and a mean reduction in visual analog scale of 5.2.[2]

USE OF PREOPERATIVE PROTOCOL

In efforts to optimize outcomes and minimize complications, protocol-based care plans have been initiated in many disciplines. Specifically, protocol-based care has been shown to successfully decrease the number of days on mechanical ventilation,[16–21] reduce the incidence of thromboembolism,[22] improve mortality from sepsis,[23,24] reduce the costs of hospitalization,[24] and reduce the incidence of drug-resistant bacterial infections.[25] Furthermore, Awissi and colleagues[26] have also shown that some protocol-based therapies can reduce overall cost. The purpose of the protocol-based interventions is to use evidence-based methods to comprehensively target specific medical issues before surgical intervention takes place. The Northwestern high-risk spine protocol[27] begins in the outpatient setting before any surgical intervention. The surgeon first determines the goals of surgery, and within that context a complete medical evaluation is initiated to determine how each of the patient's comorbidities can be optimized within the specific context of the planned surgical intervention. The protocol is designed for patients who will require more than 6 hours of surgery time, and for whom the surgeon plans more than 6 fusion levels or plans a staged procedure. The protocol is also initiated in the setting of specific medical comorbidities such as coronary artery disease, congestive heart failure, cirrhosis, dementia, emphysema, renal insufficiency, cerebrovascular disease, pulmonary hypertension, and age older than 80 years. The protocol can also be initiated in any instance whereby the clinical judgment of surgeon, internist, and/or anesthesiologist determines that the patient should be on the protocol (**Figs. 1** and **2**).[27]

The use of protocol-based therapies is designed to provide a comprehensive evaluation that can be discussed among all the care teams, including the surgeon, internist/hospitalist, anesthesiologist,

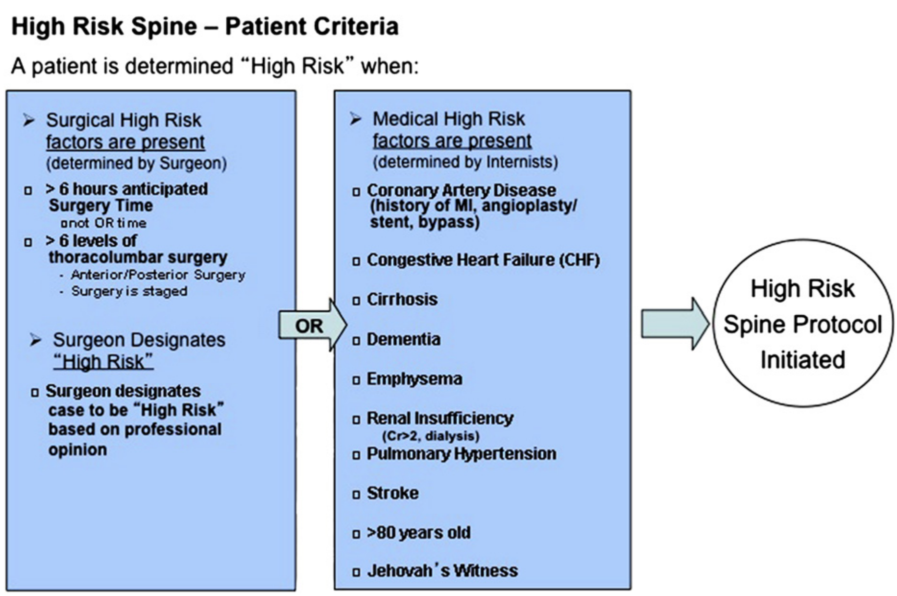

Fig. 1. Initiation of the high-risk spine protocol is based on the complexity of planned surgical intervention, patient-specific medical comorbidities, and clinical judgment.

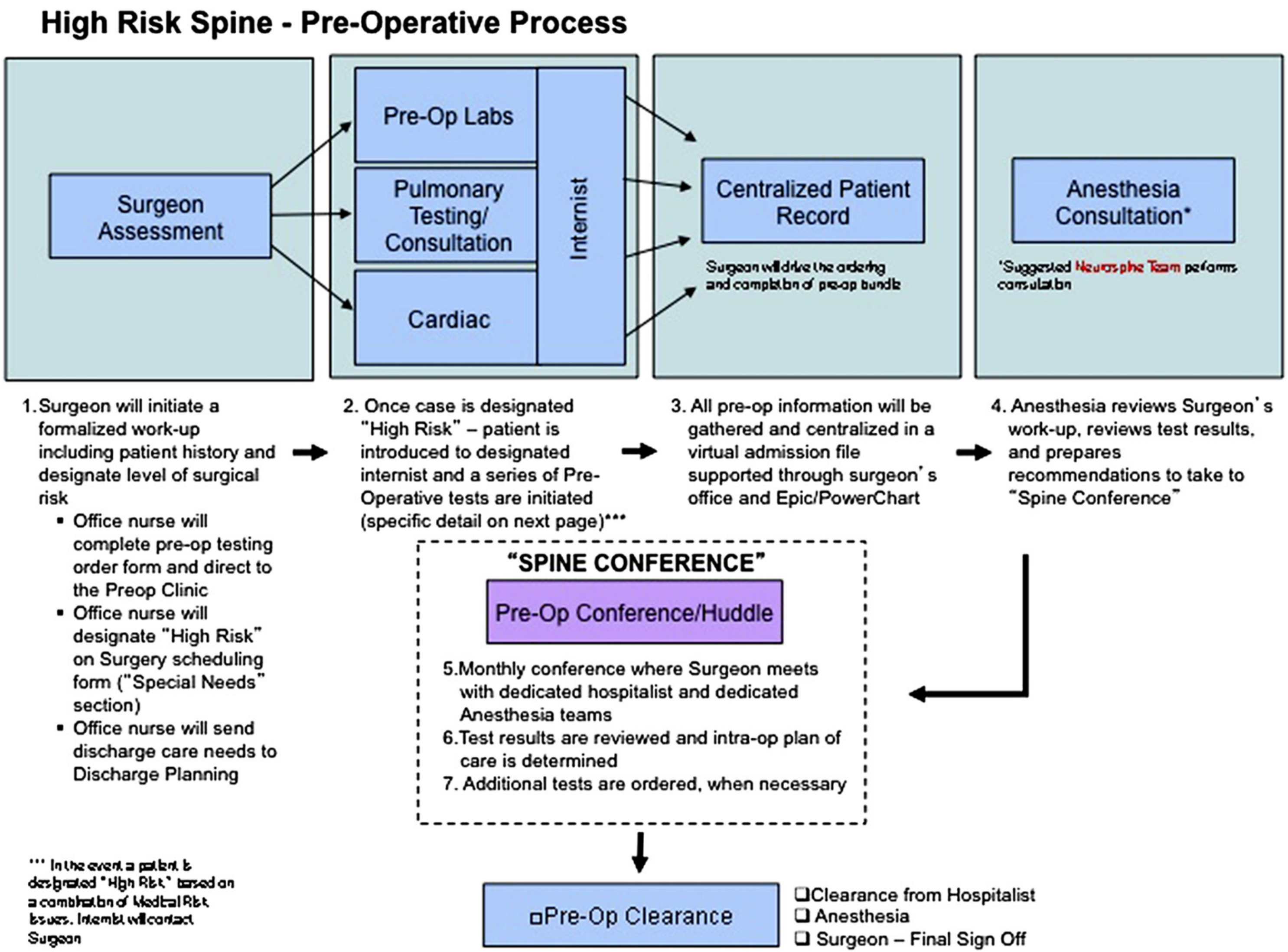

Fig. 2. The preoperative evaluation of a patient scheduled to undergo high-risk spine surgery begins in the clinic setting and continues through evaluation by the internist/hospitalist, anesthesiologist, and critical care team, to create a comprehensive evaluation and medical optimization.

and critical care physician, so as to fully understand the risk profile for the patient within the context of the patient's specific medical history and the planned surgical intervention. With this information the surgeon can have a detailed discussion with the patient addressing a true patient-specific risk profile for the planned procedure. With this in mind, a key element of the protocol is communication between the various teams involved. Each member of the high-risk team provides a unique skill set. By using the established protocol, each team member can better understand and appreciate the importance or goal of each intervention specific to the patient. Likewise, the importance of communication between the team members cannot be overemphasized as the patient transitions from the clinic, to the operating room, to the intensive care unit.

In the Northwestern high-risk spine protocol, areas specifically addressed include the patient's cardiac, pulmonary, hepatic, renal, nutritional (including bone quality), and psychosocial status.[27]

Cardiac Evaluation

According to the American College of Cardiology and American Heart Association, the following conditions have been identified as increasing the risk of perioperative cardiac complications: unstable coronary syndromes, decompensated heart failure, significant arrhythmias, or severe valvular disease. The presence of any one of these conditions may require the delay or cancellation of any nonemergent surgical intervention. Patients with a history of ischemic heart disease, history of compensated or prior heart failure, history of stroke, diabetes mellitus, renal insufficiency, or poor exercise tolerance from smoking or limited activity due to pain may also require additional workup, including a stress test or consultation with a cardiologist.[28] Often these patients will benefit from the use of a β-blocker with a goal heart rate of 55 to 65 beats/min, which has been shown to lead to a 90% reduction in cardiac events at 30 days postoperatively as well as a reduction in 1- and 2-year mortality rates.[29]

Pulmonary Evaluation

Pulmonary complications in the postoperative setting include pneumonia, pleural effusions, respiratory failure, with prolonged mechanical ventilation, bronchospasm, atelectasis, and exacerbations of chronic lung disease, and can be just as common as cardiac complications.[3,30] Presence of decreased breath sounds, dullness to percussion, wheezes, rhonchi, or prolonged expiratory phase in the preoperative evaluation predict an increased risk of pulmonary complications postoperatively.[30,31] Furthermore, 64% of patients will have some form of abnormality on postoperative chest radiograph, including atelectasis, pleural effusion, infiltrate, or lobar collapse, and patients with radiographic changes also tend to have a longer mean length of stay[3,14] The use of a ventilator-weaning protocol by Blackwood and colleagues[32] demonstrated a reduction in duration on mechanical ventilation and length of stay in the intensive care unit. Poor exercise tolerance/capacity is defined by the inability to perform 2 minutes of supine bicycle exercise sufficient to raise the heart rate to 99 beats/min, and predicts 79% of pulmonary complications in patients undergoing surgical intervention.[33] In patients with cough, dyspnea, or exercise intolerance, consideration should be given to evaluation by a pulmonary specialist, and pulmonary function tests (PFTs) should be obtained.[34] In children undergoing scoliosis surgery, PFTs decreased by as much as 60% postoperatively, reaching a nadir approximately 3 days after surgery.[35] Patients undergoing a transthoracic approach are much more likely to develop pulmonary complications,[36,37] so the decision to use a transthoracic versus a posterior-only based approach must be considered in the preoperative discussion.

Patients with chronic obstructive pulmonary disease (COPD) are at increased risk for pleural effusion and/or pneumonia, and treatment with bronchodilators, physical therapy, antibiotics, smoking cessation, and corticosteroids can help reduce this risk.[34,38–40] Smoking has been shown to significantly increase the risk of pulmonary complications postoperatively. The relative risk of pulmonary complication rates in smokers compared with nonsmokers is 1.4 to 4.3.[27,34] Patients with an acute COPD exacerbation are at increased risk of complications and should consider delaying surgery.[40] In patients undergoing coronary artery bypass surgery, Warner and colleagues[41] have demonstrated that smoking cessation less than 8 weeks before undergoing surgery is associated with a higher risk than is active smoking.

In the setting of surgery involving high blood loss, such as spinal deformity correction, high blood-transfusion requirements place the patient at increased risk for transfusion-related acute lung injury (ALI). Moreover, protocol-based therapies such as lung-protective strategies have helped reduce the morbidity and mortality associated with ALI.[42,43] Acute respiratory distress syndrome (ARDS) and other forms of ALI are associated with critically ill patients and potential complications following spinal surgery.[44–46]

Hepatic Evaluation

Patients with chronic liver disease are at risk for increased morbidity and mortality following surgical procedures[47] whereby the most common complications are secondary to acute or chronic liver failure leading to severe coagulopathy, encephalopathy, ARDS, acute renal failure, and sepsis.[48] As part of the comprehensive preoperative assessment, the use of the Model for End-Stage Liver Disease (MELD) can be a useful predictor of mortality in patients with liver disease. Northup and colleagues[49] reported a direct correlation between MELD scores and postoperative mortality, demonstrating that a MELD score of less than 10 predicts a low likelihood of complication whereas a score greater than 20 suggests a high risk of complication. Furthermore, patients with acute viral or alcoholic hepatitis, fulminant hepatic failure, severe chronic hepatitis, Child-Pugh class C cirrhosis, severe coagulopathy, or severe extrahepatic complications such as hypoxia, cardiomyopathy, or acute renal failure should not undergo elective surgery.[27]

Renal Evaluation

Patients with chronic renal failure or dialysis-dependent end-stage renal disease (ESRD) are at risk for osteoporosis, electrolyte imbalances, and anemia, which can each complicate the intraoperative and postoperative course. In particular, patients at risk for osteoporosis are also at risk for pseudarthrosis, which may influence the planned surgical intervention biomechanically when considering fusion levels, circumferential procedures, type and material of instrumentation used, or the use of osteobiologics.[50–52] The most common abnormality found in patients with ESRD is hyperkalemia, so electrolyte levels should be monitored closely in conjunction with overall fluid balance.[53,54] Patients with ESRD should be dialyzed within 24 hours after surgery.[53]

Nutrition Evaluation

Risk factors for poor nutrition status include age older than 60 years, diabetes, osteomyelitis, and spinal cord injury.[29,55] The metabolic demands on a patient following major spinal reconstruction are likely much higher than their baseline metabolic needs, therefore nutritional status before surgery can greatly affect outcome. Preoperative albumin level, prealbumin level, and total lymphocyte counts can be useful for estimating nutritional reserves, as nutritional stores following major reconstructive surgery can take 6 to 12 weeks to return to baseline.[56] The use of hyepralimentation with total parenteral nutrition during the perioperative period, particularly in the setting of staged procedures, can be used to augment nutritional stores.[57]

Aggressive glucose control is associated with improved outcomes, as diabetes or poor glucose control has been shown to increase the risk of infection and pneumonia as well as the length of stay in hospital and the intensive care unit.[27,29,55,58–61] The use of protocol-driven therapies in the intensive care unit has shown that using an intensive glucose control protocol designed to maintain serum glucose levels at 110 mg/dL reduced in-hospital mortality by 34%, bloodstream infections by 46%, acute renal failure by 41%, and the rate of red blood cell transfusions by 50%.[62] Hemmila and colleagues[63] have also demonstrated a reduced incidence of pneumonia and urinary tract infection in burn patients with intensive glucose control.

Osteoporosis, as defined by a bone mineral density more than 2.5 standard deviations below peak bone mineral density, measured using dual-energy radiograph absorptiometry, can lead to increased rates of proximal junctional kyphosis, pseudarthrosis, and distal screw loosening.[64] Risk factors for osteoporotic fractures include Caucasian race, age older than 50 years, postmenopausal status, active smoking, history of any fracture sustained after age 40 years, or history of fractures of the hip, spine, or wrist in a first-degree relative.[65] In addition to nutritional supplementation with calcium and vitamin D, antiresorptive agents such as bisphosphonates, calcitonin, estrogens, and estrogen-receptor modulators have been used to treat osteoporosis, but animal studies have shown varying effects on the amount of fusion mass and radiographic evidence of fusion.[66–69] More recently, teriparatide has been introduced as an alternative to the antiosteoclastic activity of bisphosphonates. Nakamura and colleagues[70] have shown that once-weekly injections of teriparatide reduced the incidence of new vertebral fractures in patients with known osteoporosis and prior fractures: 3.1% in the teriparatide cohort compared with 14.5% in the placebo cohort. Furthermore, Ohtori and colleagues[71] demonstrated an increased fusion rate and decreased time to radiographic fusion in osteoporotic women with degenerative spondylolisthesis undergoing decompression and instrumented posterolateral fusion with teriparatide compared with bisphosphonate. Transient exposure to parathyroid hormone has been shown to improve bone formation by altering the activities of osteoblasts, osteoclasts, and osteocytes.[72] Potential side effects include hypercalcemia and hypercalciuria, and studies in animals have shown only some increase in sarcoma formation.[72]

Thromboembolism

Rates of deep venous thrombosis (DVT) after spine surgery have been reported widely in the literature, ranging from 0.3% to 31%.[73–84] Owing to concerns for postoperative hematoma formation and potential severe neurologic decline, the use of chemical DVT prophylaxis among spine surgeons varies widely. However, the use of DVT prophylaxis protocols in specialties such as orthopedics, general surgery, and plastic surgery has been shown to reduce the incidence of DVT and pulmonary embolism.[22,85,86] The application of such a protocol must take into consideration the preoperative risk factors of the specific patient and must include the intraoperative findings. A podium presentation from the Scoliosis Research Society Annual Meeting reviewed 445 high-risk patients who were given prophylactic low molecular weight heparin on average postoperative day 4 (42% within 72 hours) without sequelae.[87] The use of prophylactic inferior vena cava filters has also been shown to reduce the risk of pulmonary embolism in particularly high-risk patients.[78,88–90]

USE OF INTRAOPERATIVE PROTOCOL

Once the preoperative risk stratification and medical optimization is complete, the patient is finally brought to the operating room for the planned surgical intervention. A key component of maximizing the benefits of the high-risk spine protocol is communication. Both the surgical and anesthetic teams must be well versed in the medical history and preoperative evaluation of the patient, and both are encouraged to discuss the goals and risks of each intervention throughout the case. Likewise, verbal communication between the surgical, anesthetic, and neuromonitoring teams occurs at least on an hourly basis and more frequently during times of higher-risk interventions such as performing osteotomies. Any change in the patient's condition is communicated immediately to all parties.

A worksheet/checklist is maintained throughout the procedure as part of the anesthetic record. Laboratory values including complete blood count, prothrombin time, partial thromboplastin time, international normalized ratio, fibrinogen,

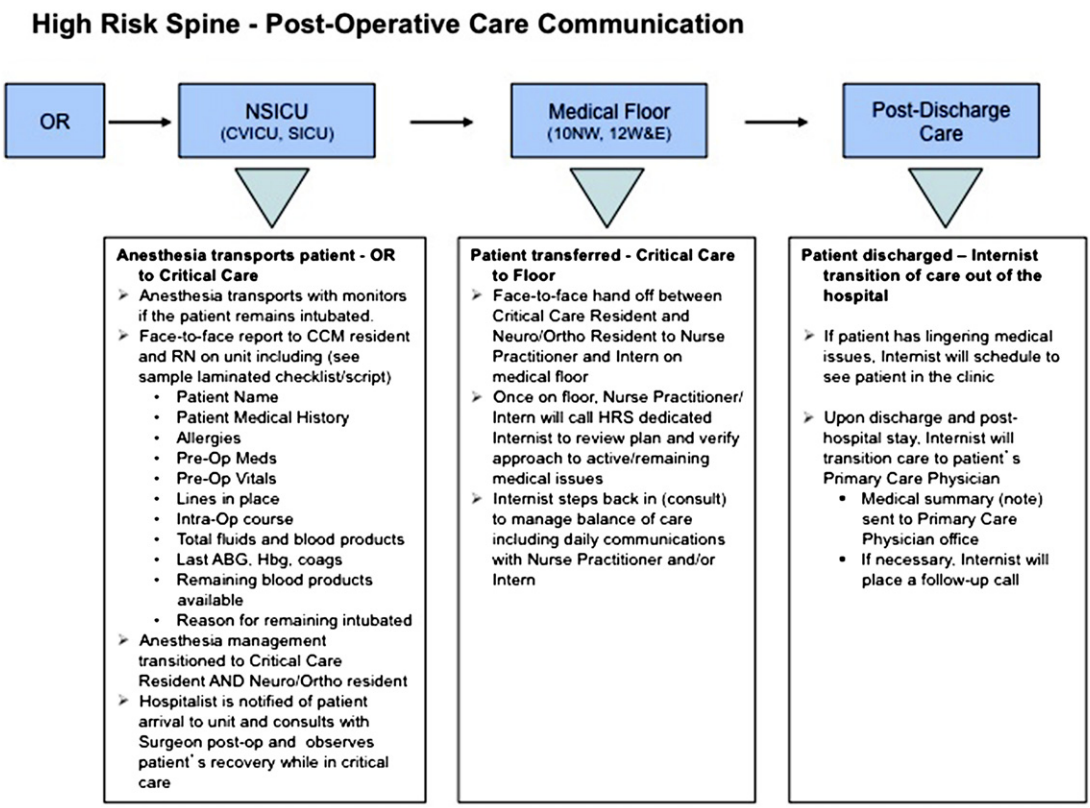

Fig. 3. A crucial element of executing the high-risk spine protocol is the use of effective and open communication as the patient advances from the clinic, to the operating room (OR), to the intensive care unit. ABG, arterial blood gas; CCM, critical care medicine; coags, coagulation studies; CVICU, cardiovascular intensive care unit; Hbg, hemoglobin; HRS, high-risk spine; NSICU, neuro-spine intensive care unit; RN, registered nurse; SICU, surgical intensive care unit.

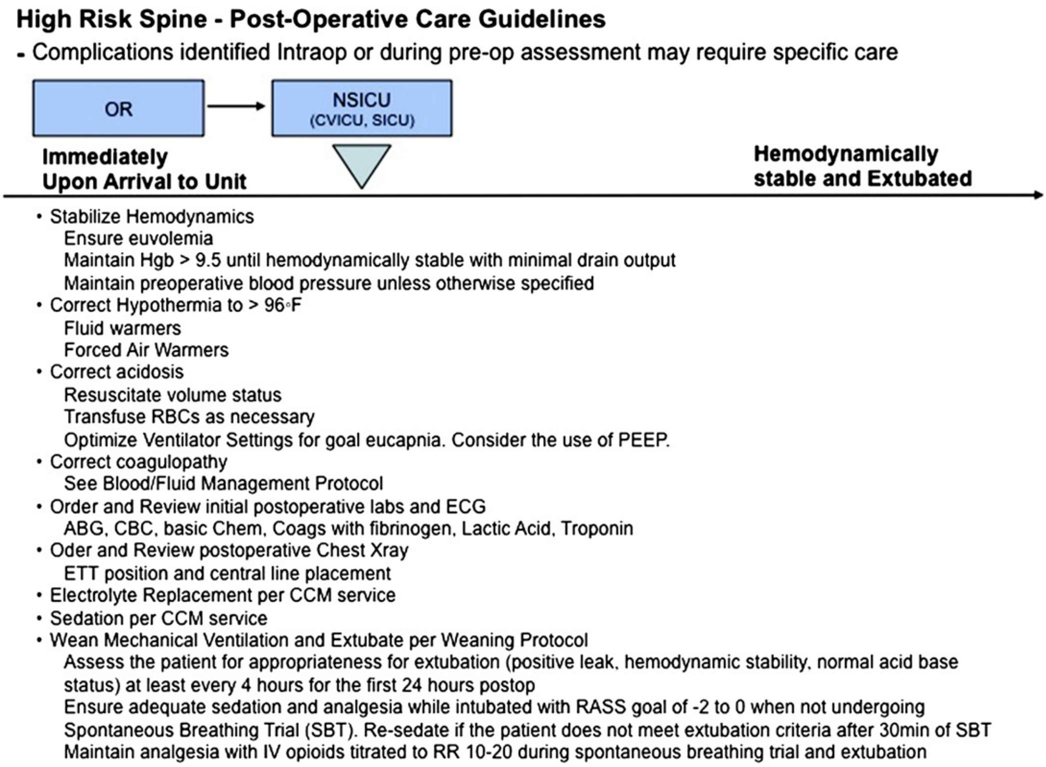

Fig. 4. On arrival to the intensive care unit, intraoperative events are discussed with establishment of immediate specific plans for resuscitation and recovery. CBC, complete blood count; ECG, electrocardiogram; ETT, endotracheal tube; IV, intravenous; PEEP, positive end-expiratory pressure; RASS, Regional Anesthesia Surveillance System; RBCs, red blood cells; RR, respiratory rate.

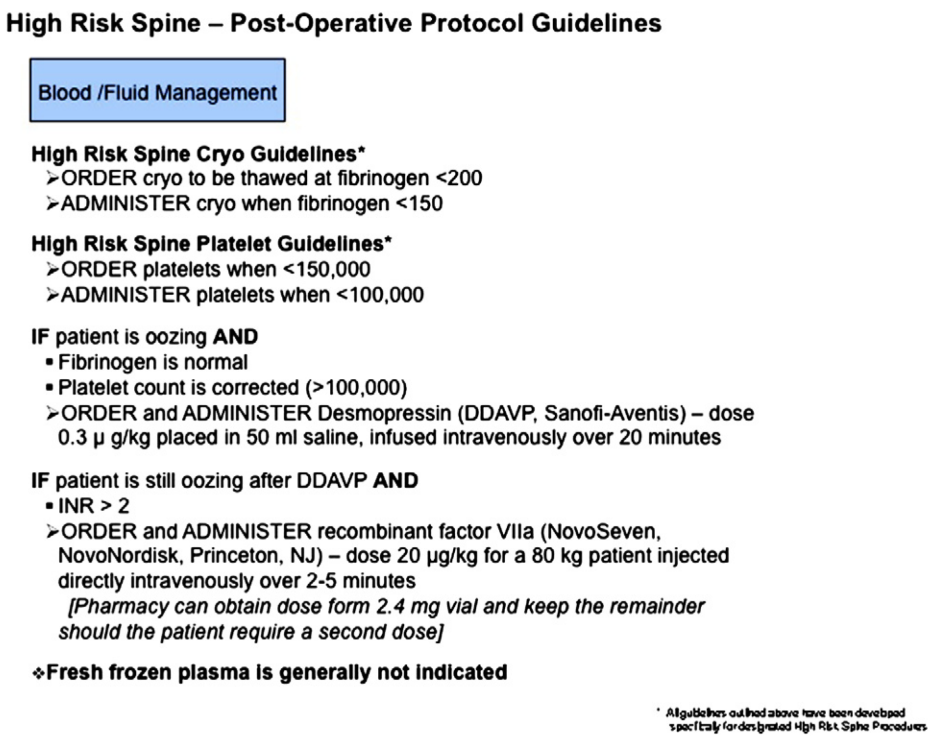

Fig. 5. Coagulation parameters and transfusion thresholds are established based on the high-risk spine protocol. INR, international normalized ratio.

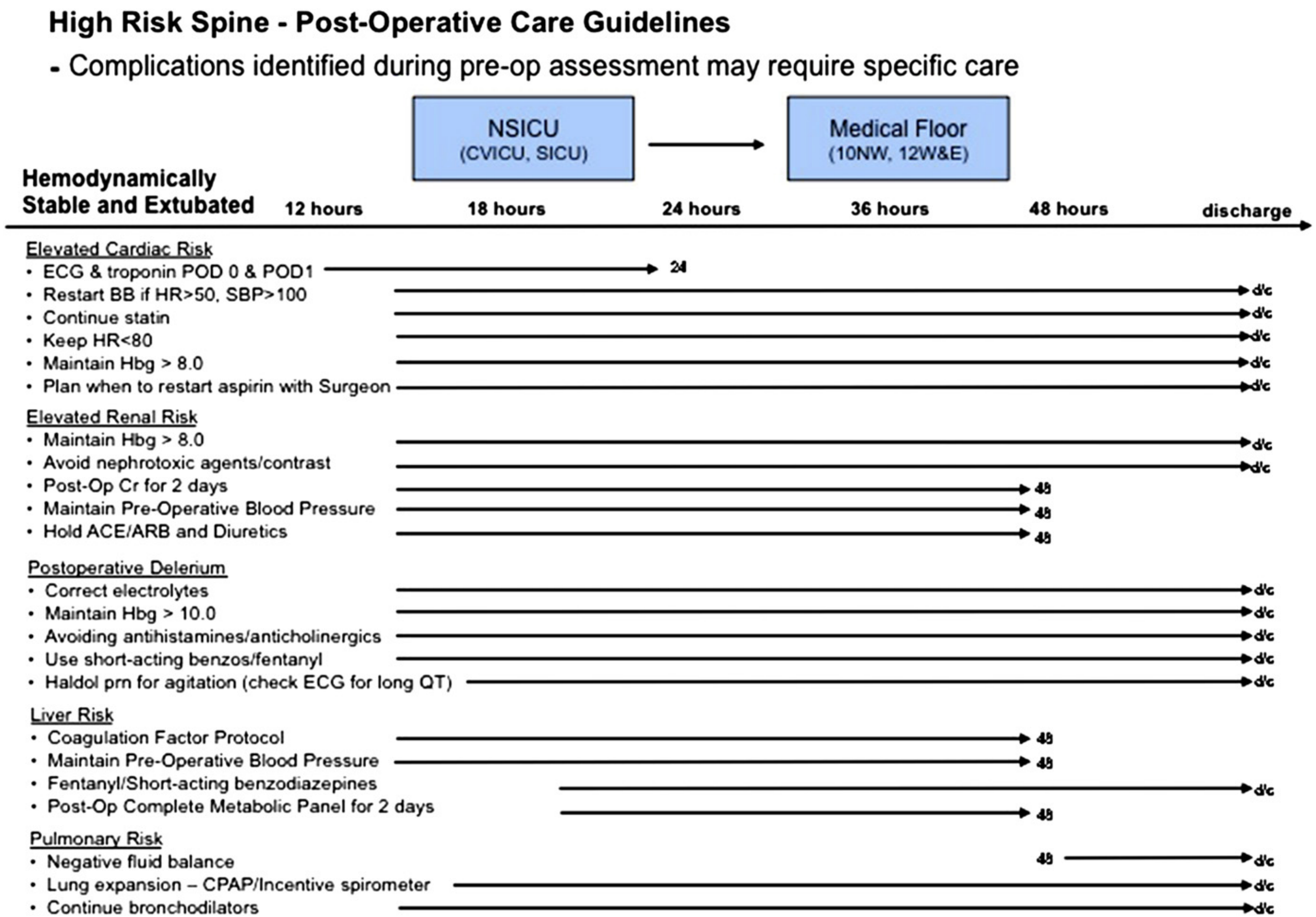

Fig. 6. Patient-specific laboratory values and clinical parameters tailored to the specific patient comorbidities are followed immediately postoperatively throughout the patient's hospital course. ACE, angiotensin-converting enzyme inhibitor; ARB, angiotensin receptor blocker; BB, β-blocker; CPAP, continuous positive airway pressure; Cr, creatinine; HR, heart rate; POD, postoperative day; SBP, systolic blood pressure.

and ionized calcium are initially followed every 2 hours, and after 6 hours they are checked and reported hourly. The transfusion protocol as presented by Halpin and colleagues[27] uses packed red blood cells, cryoprecipitate, platelets, desmopressin, and activated factor VII, but does not use fresh frozen plasma because of the excessive volume associated with it.

The use of antifibrinolytics has become increasingly common in spinal deformity operations. Aprotinin, ε-aminocaproic acid, and tranexamic acid have all been used in various studies. A meta-analysis by Gill and colleagues[91] determined that all 3 agents are effective at reducing blood loss and transfusion requirements in patients undergoing spine surgery, and that both ε-aminocaproic acid and tranexamic acid do so without increasing the risk of a thromboembolic event. Elwatidy and colleagues[92] confirmed the efficacy and safety of tranexamic acid in a randomized, double-blind, placebo-controlled trial of 64 adult patients undergoing high-blood-loss spinal procedures, and Yagi and colleagues[93] likewise demonstrated a reduction in blood loss and blood-transfusion requirements in 106 adolescents undergoing posterior spinal fusion. The use of antifibrinolytics during high-risk spine surgery has become part of the standard protocol for many institutions, and can help reduce complications associated with significant blood loss/anemia and transfusion-related reactions.

USE OF POSTOPERATIVE PROTOCOL

Following the completion of the procedure, the patient is transported to the neuro-spine intensive care unit (NSICU), and a face-to-face report from the anesthesia team is given to the critical care team along with the surgical team (**Figs. 3** and **4**). The intraoperative checklist is reviewed and a new set of laboratory values is established. Postoperative resuscitation and subsequent transfusion is performed according to the high-risk spine protocol and is tailored to the needs of that specific patient (**Figs. 5** and **6**). Specifically, in the setting of active hemorrhage or high subfascial drain output the coagulation profile is determined, which may necessitate transfusion of blood product clotting factor. Once the patient is fully resuscitated, the use of restrictive transfusion strategies is typically implemented[94,95] and the ventilator-weaning protocol is initiated. At this time the hospitalist who evaluated the patient preoperatively then engages again in helping to manage the patient's ongoing medical issues until the time of discharge. At the time of discharge a summary letter is sent to the patient's primary care physician for established follow-up.

SUMMARY

The use of early goal-directed evidence-based therapies has led to improved outcomes and has helped to minimize complications.[23,24] The Institute for Healthcare Improvement in the Surviving Sepsis Campaign advocates for widespread adoption of the bundle protocol with a program of "education, practice improvement, and performance measurement" in the treatment of sepsis.[23,96] Likewise, the application of protocol-based care in the treatment of complex spinal pathology in an aging and medically complex patient population helps to unify and direct the various medical and surgical subspecialists toward one overall patient goal. In this context, the protocol provides a comprehensive evaluation of the patient that also helps the transition of care from the outpatient setting through surgery and until the time of discharge, with multiple transitions of care among health care providers. The goal of this or any protocol-based therapy is to improve outcomes through improved communication and collaboration between health care providers when caring for these medically and surgically complex patients.

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