

# Surgical Risk Assessment and Prevention in Elderly Spinal Deformity Patients

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## Abstract

**Introduction:** Prevalence of adult deformity surgery in the elderly individuals continues to increase. These patients have additional considerations for the spine surgeon during surgical planning. We perform an informative review of the spinal and geriatric literature to assess preoperative and intraoperative factors that impact surgical complication occurrences in this population. **Significance:** There is a need to understand surgical risk assessment and prevention in geriatric patients who undergo thoracolumbar adult deformity surgery in order to prevent complications. **Methods:** Searches of relevant biomedical databases were conducted by a medical librarian. Databases searched included MEDLINE, Web of Science, CINAHL, IPA, Cochrane, PQ Health and Medical, SocINDEX, and WHO's Global Health Library. Search strategies utilized Medical Subject Headings plus text words for extensive coverage of scoliosis and surgical technique concepts. **Results:** Degenerative scoliosis affects 68% of the geriatric population, and the rate of surgical interventions for this pathology continues to increase. Complications following spinal deformity surgery in this patient population range from 37% to 62%. Factors that impact outcomes include age, comorbidities, blood loss, and bone quality. Using these data, we summarize multimodal risk prevention strategies that can be easily implemented by spine surgeons. **Conclusions:** After evaluation of the latest literature on the complications associated with adult deformity surgery in geriatric patients, comprehensive perioperative management is necessary for improved outcomes. Preoperative strategies include assessing physiological age via frailty score, nutritional status, bone quality, dementia/delirium risk, and social activity support. Intraoperative strategies include methods to reduce blood loss and procedural time. Postoperatively, development of a multidisciplinary team approach that encourages early ambulation, decreases opiate use, and ensures supportive discharge planning is imperative for better outcomes for this patient population.

## Keywords

adult deformity, degenerative scoliosis, elderly, geriatric, surgical risk, risk assessment, risk prevention

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## Introduction

Adult degenerative scoliosis results from the asymmetric degeneration of intervertebral disks and facet joints that lead to spinal column malalignment/deformity.<sup>1,2</sup> The prevalence of adult degenerative scoliosis increases with age.<sup>3,4</sup> As the population's life span increases, the world's population of people older than 60 will triple in size by 2050.<sup>5</sup> Therefore, this is a significant public health issue as degenerative scoliosis affects 68% of the elderly population.<sup>6</sup> Given recent surgical advances and further understanding of the etiopathology on this condition, there has been a paradigm shift in treating qualifying elderly patients with surgical intervention rather than medical management.<sup>7-9</sup> Surgical intervention for adult spinal deformity among patients older than 60 increased 3.4-fold from 2004 to 2011.<sup>10</sup> Among the adult population, the rate of spinal

deformity cases increased from 4.16 per 100 000 adults to 13.9 per 100 000 adults from 2001 to 2013.<sup>11</sup> From 2003 to 2012, surgical management of adult deformity increased and surgical morbidity decreased in the elderly individuals.<sup>12</sup>

Surgical management of degenerative scoliosis involves decompression of the neural elements and fusion to realign the

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involved spinal segments. Oftentimes extensive multilevel spine surgery is required to achieve both coronal and sagittal alignment.<sup>13</sup> Surgical risk assessment is critical to estimating postoperative complications that impact a wide range of factors from informed consent discussions to operative planning.<sup>14</sup> Complication rates following adult deformity surgery can be up to 55%.<sup>15-17</sup> The risks–benefits analysis required in evaluating elderly patients for deformity spinal surgery for the treatment of degenerative scoliosis is complex.

Adult degenerative scoliosis causes progressive disability and severely impacts quality of life more than other chronic conditions such as diabetes and congestive heart failure.<sup>18</sup> Few studies have evaluated outcomes in cohorts of elderly patients with this condition who have undergone surgery. However, given the continual increase in the aging population, spine surgeons will continue to be challenged to deliver adequate care to the elderly population. In this review, we analyzed both the surgical and geriatric literature to allow spine surgeons' tools to critically evaluate surgical risk and subsequently develop risk prevention strategies for elderly adult deformity patients.

## Methods

An informative review of the literature was performed using biomedical databases across 4 vendor platforms and the World Health Organization's Global Health Library website. MEDLINE and MEDLINE In Process & Daily Updates plus International Pharmaceutical Abstracts were searched via the OVID platform. The EBSCO platform was utilized for searching the Cumulative Index to Nursing and Allied Health Literature-CINAHL Complete, SocINDEX, as well as Cochrane Central Register of Controlled Trials, Cochrane Database of Systematic Reviews, Cochrane Methodology Register, and Cochrane Clinical Answers. ProQuest's interface was used to search the PQ Health and Medical database. Science Citation Index and Social Sciences Citations Index were both researched via Web of Science.

The research team identified all pertinent concepts and consulted on specific terminology. Search strategies were piloted and refined based on team's reviews of sample results. All search strategies were created by medical librarian coauthor (S.C.S.), and final strategies were run in early to mid-October 2018. Controlled vocabulary terms were combined with advanced text word search techniques including adjacency, nesting, and truncation for each main concept. Specific Medical Subject Headings (MeSH) utilized and exploded (to incorporate more specific headings under the MeSH terms) for concept 1 included: spinal curvatures, scoliosis, kyphosis, lordosis or spinal diseases specific to spine deformity, degeneration, and misalignment. The surgical subheading was used in some search strings. Concept 2 was surgical techniques that included MeSH headings: surgical decompression, arthrodesis, osteotomy, spinal fusion, bone screws, or pedicle screws. The third concept covered age-related risk factors and outcomes: age factors, Alzheimer disease, dementia, delirium, hemorrhage, surgical blood loss, failed back surgery syndrome, treatment failure, and treatment outcome are a few of the MeSH

headings utilized. The main MEDLINE strategy was adapted to include appropriate controlled vocabulary headings and text word searching combinations as required for specific database platforms. All final strategies covered 1998 to 2018 and were limited to English language. Articles that focused on scoliosis of the cervical region were excluded at the search strategy level. All results were filtered for the elderly individuals (65 and older). Results were exported to EndNote X6 (Clarivate Analytics, Philadelphia, PA, USA) and duplicate records were removed. The final unique set of results was then sent to the team for analysis.

## Predictors of Complications

In order to evaluate factors that determine surgical risk, we assessed predictors of complications following spine surgery for scoliosis in the elderly individuals. Few studies were available that included this cohort of patients. In an analysis of over 2000 geriatric patients (aged older than 80) who underwent lumbar surgery, factors associated with increased risk of complication and readmission include baseline functional status and the length and complexity of the surgical procedure. All lumbar spinal surgeries performed for the diagnoses of lumbar stenosis and spondylolisthesis were included; the diagnosis of scoliosis was not explicitly queried.<sup>19</sup> Blood loss and history of a previous spine surgery were associated with morbidity in another study of patients older than 80 years who had lumbar degenerative spine surgery.<sup>20</sup> However, it is very likely that a portion of patients from both of these studies were treated for degenerative scoliosis, but results of patients who underwent multilevel fusion were not separated from the larger cohort.

Age greater than 80 was associated with the highest risk of mortality in patients who underwent spinal fusion.<sup>21</sup> Patients older than 60 who required 5 or more levels of fusion for spinal deformity correction had an overall complication rate of 37%. Increasing age and undergoing a pedicle subtraction osteotomy (PSO) were associated with increased complications. A patient older than 69 had 9 times the risk of a major complication than a patient younger than 69. Patients who underwent a PSO were 7 times more likely to have a major complication than those who did not.<sup>22</sup> Pedicle subtraction osteotomy and vertebral column resection can significantly improve sagittal and coronal balance in the elderly individuals but can lead to serious complications.<sup>23</sup> The fusion of multiple segments in the elderly individuals is also a risk factor for postoperative complications.<sup>24</sup> Patients older than 75 years undergoing spinal deformity surgery that required fusion of 5 or more levels had perioperative complication risks of 62%. Hypertension was the most predictive comorbidity of perioperative complication in this cohort.<sup>25</sup> Increasing age also directly correlates with the need for revision surgery in adults following index spinal deformity surgery.<sup>26,27</sup> Preexisting anemia was an independent predictor of 30-day readmission in elderly spine patients who underwent deformity correction.<sup>28</sup>

Despite age itself being a risk factor for complications in many studies, some studies did not find a correlation between

**Table 1.** Frailty Assessment Tools.

Name	Grades of Frailty	Assessment Method	Pros/Cons
Edmonton Frail Scale <sup>42</sup>	0- to 17-point scale (ranging from not frail to severe frailty)	Questionnaire	<ul style="list-style-type: none"> <li>• Pros: Quick assessment method (&lt;5 min), can be administered by nonspecialists</li> <li>• Cons: Not suitable for emergency situations, patients who do not speak English, or who are hearing or vision impaired</li> </ul>
Clinical Frailty Scale <sup>34,43</sup> ; CSHA Frailty Scale <sup>39</sup>	1- to 9-point scale (ranging from very fit to terminally ill); 1- to 7-point scale (ranging from very fit to severely frail)	Clinical judgment	<ul style="list-style-type: none"> <li>• Pros: Easy to use and implemented in outpatient clinical setting, clinically feasible</li> <li>• Cons: Subjective assessment, has only been validated for use by specialists</li> </ul>
The Fatigue, Resistance, Ambulation, Illness and Loss of weight (FRAIL) Index <sup>17</sup>	0- to 5-point scale (ranging from health status to frail)	Questionnaire	<ul style="list-style-type: none"> <li>• Pros: Simple questionnaire for first step frailty screening, can be administered by telephone or self-administered</li> <li>• Cons: Low sensitivity in predicting incident physical limitation and mortality<sup>44</sup></li> </ul>
Groningen Frailty Indicator (GFI) <sup>33,45</sup>	0- to 15-point scale (ranging from normal to completely disabled)	Questionnaire	<ul style="list-style-type: none"> <li>• Pros: GFI subscale scores has good feasibility and reliability as a frailty measurement.</li> <li>• Cons: Using a cutoff score may not be accurate, and conditional criteria may be needed to establish a more convergent diagnosis<sup>46</sup></li> </ul>
Tilburg Frailty Indicator <sup>47,48</sup>	0- to 15-point scale (ranging from normal to frail)	Questionnaire	<ul style="list-style-type: none"> <li>• Pros: Easy to administer. Good validity, test-retest reliability, and ability to predict adverse outcome.<sup>19</sup></li> <li>• Cons: This self-report instrument is not suitable for patients who have problems with cognitive functioning<sup>32</sup></li> </ul>

age and complications in patients undergoing deformity surgery.<sup>10,24,29-31</sup> Thirty-day morbidity and mortality were similar between elderly patients undergoing combined anterior/posterior compared to those undergoing posterior alone for spinal deformity.<sup>32</sup> Medicare patients older than 65 years of age were less likely to be reoperated or readmitted in comparison to Medicare patients younger than 65 years of age following lumbar spine surgery.<sup>33</sup> However, although there was a more than 3-fold increase in the first decade of the 21st century among spinal deformity surgery among the elderly individuals, the in-hospital complication rate was stable between all age groups.<sup>10</sup> Yoshida et al developed a scale to predict perioperative complications following spinal deformity surgery based on a retrospective analysis of 304 patients. Patients' age, medication, and type of deformity were independent preoperative predictors of risk.<sup>34</sup>

Adult patients who require revision surgery have higher complication rates than patients undergoing primary scoliosis surgery. Adjacent segment disease is the most common cause for revision surgery.<sup>35,36</sup> Interestingly, in Cho et al's cohort, patients older than 60 years of age who underwent primary or revision scoliosis surgery had similar clinical outcome measures.<sup>37</sup> However, age and number of levels fused were most predictive of extended hospital stay and intraoperative blood loss.<sup>38</sup> These data indicate that chronological age alone is not the main determinant of risk. An informative assessment of multiple factors is needed in this patient population.

## Surgical Risk Assessment

### Age and Frailty

Advanced age carries an increased risk of surgical complications, but chronological age is not the same as physiological age. Rather than focusing on age, frailty, a geriatric syndrome characterized by decreased physiological reserve, has been found to be a better predictor of postoperative morbidity and mortality.<sup>39</sup> Frailty has been useful in predicting poor surgical outcomes for patients from multiple specialties including general surgery, surgical oncology, vascular surgery, orthopedics, and urology.<sup>40,41</sup> Frailty assessment can be done based on clinical judgment or administering a questionnaire. Five common clinical tools used to evaluate frailty are outlined in Table 1. Two of the frailty scales involve the use of clinical judgment to ascertain functional capability similar to a performance score. However, for surgeons without significant experience in geriatrics, clinical judgment tools may not be the most accurate for risk assessment. Certain frailty scales, such as the Edmonton frailty scale, assess overall health status, cognition, social support, medication use, nutrition, continence, and functional performance.<sup>49</sup> These scales involve questionnaires and can be filled out prior to the clinical encounter.

Recent studies have begun to evaluate how frailty assessment can be used in surgical spine patients. An analysis of the National Surgical Quality Improvement Program (NSQIP) data for patients undergoing spine surgery from 2006 to 2010 demonstrated that the modified frailty index was associated

with an increased risk of a life-threatening complication and death.<sup>43</sup> In patients undergoing spine surgery for degenerative disease, frailty was predictive of major complication, reoperation, and mortality.<sup>46,50,51</sup> For adult patients who had surgery for spinal deformity, frailty was also found to be a predictor for these same 3 outcomes.<sup>52</sup> This clinical parameter should be integrated into the preoperative risk assessment. A frailty index that uses a panel of urine and blood tests is also available and is comparable to other clinical frailty indexes.<sup>53</sup> This allows for another method of evaluation with potential for practical utility in a busy spine practice.

### Nutritional Status

Nutritional status is another important parameter in the elderly adult deformity patient as it plays a major role in postoperative recovery and wound healing.<sup>54,55</sup> Malnutrition predisposes patients to infection as well. The main reason for reoperation in adult spinal deformity surgery is infection.<sup>56</sup> Malnutrition is an independent risk factor for infection and wound complications following posterior lumbar surgery.<sup>57</sup> In elderly orthopedic patients, malnutrition was found to correlate with prolonged hospitalization, delayed mobilization, and mortality.<sup>58,59</sup> In patients aged 65 to 84 years who underwent elective 1- or 2-level spine surgery, malnutrition was correlated with incidence of major complication and was a predictor of increased infection and wound dehiscence.<sup>60</sup>

Nutrition assessment can be done by asking the patient about recent weight loss, obtaining body mass index (BMI), and physical examination. Patient self-reported weight loss is often integrated into many frailty indexes.<sup>49</sup> Formal screening tools for malnutrition include the subjective global assessment of nutritional status, the nutritional risk screening tool, and the Mini-Nutritional Assessment questionnaire.<sup>61</sup> These evaluations may be cumbersome, with the average time to complete the Mini-Nutritional Assessment questionnaire of 10 to 15 minutes.<sup>62</sup>

The assessment of protein status via laboratory data is used as a surrogate method to evaluate nutrition. Serum albumin of 3.5 g/dL or less (ie, hypoalbuminemia) is an independent risk factor for mortality, complications, wound infection, and thromboembolic disease in adults who had spinal fusion.<sup>21</sup> Low preoperative albumin level is also a risk factor for patients after elective spine surgery for degeneration and deformity.<sup>63</sup> Prealbumin can also be used with a threshold value of 11 mg/dL. Patients with low (<11 mg/dL) perioperative prealbumin levels who underwent long fusion constructs ( $\geq 7$  segments) were more likely to develop an infectious complication.<sup>64</sup>

Malnutrition is often the focus of surgical risk assessment, but obesity is a consideration as well. In one study, morbidly obese patients who undergo elective spine surgery have increased odds of complications, readmission, and reoperation.<sup>65</sup> However, in patients with degenerative scoliosis who required multiple levels of fusion, obesity did not increase postoperative complications.<sup>66</sup> A more recent evaluation of data from the National Neurosurgery Quality and Outcomes

Database also did not find significant outcome differences between obese and nonobese patient undergoing lumbar surgery.<sup>67</sup> These contrasting results may be secondary to body mass distribution. Increased subcutaneous fat thickness was a better indicator of surgical site infection risk than BMI.<sup>42,68</sup> When thoracolumbar scoliosis surgery was done with a combined anterior/posterior approach, outcomes were worse in obese patients likely related to the technical difficulty in this cohort.<sup>29</sup> This indicates that body habitus should be considered when choosing surgical approach. How obesity affects outcomes in elderly patients who require spinal deformity surgery is unknown at this time.

### Bone Density

Bone density is an important factor in surgical planning, especially when multiple levels of fusion are required. The prevalence of osteoporosis is increased in the elderly population and can create further considerations to altering the surgical plan. Bone quality evaluation for patients requiring spine surgery is recommended especially in women older than 50 years.<sup>69</sup> The most common method to measure bone mineral density is by dual energy X-ray absorptiometry (DXA). However, trabecular bone score can aid in evaluating bone microarchitecture providing information not available by DXA.<sup>70</sup> Vitamin D measurements with a goal serum 25(OH) D concentration of >30 ng/mL can be integrated in bone quality assessment of spine surgery patients.<sup>71</sup> In elderly spinal deformity patients who required a minimum of 5 fusion levels, poor bone quality was associated with early complications such as pedicle and compression fractures. Bone quality also was associated with late complications of pseudarthrosis, adjacent-level disease, and progressive kyphosis.<sup>72</sup> Bone density and quality evaluation is therefore an important measure for spine surgeons to conduct preoperatively.

### Dementia/Delirium Risk

The prevalence of delirium in the perioperative period is increased in the elderly population. Preexisting dementia is one of the main risk factors for developing delirium.<sup>73</sup> Among older patients undergoing lumbar spine surgery, the prevalence of preoperative cognitive impairment was 38%.<sup>74</sup> In elderly patients undergoing elective spine, risk factors for the development of delirium during postoperative hospitalization included prolonged anesthesia greater than 3 hours, greater blood loss, intraoperative hypotension, intraoperative hypercapnia, and polypharmacy.<sup>75-78</sup> The development of delirium is an independent risk factor for readmission in elderly spine surgical patients.<sup>79</sup> For patients aged 70 years and older, delirium was a risk for longer hospital stay, increased cost over the admission period, and less likelihood of discharge to home.<sup>80</sup> Depression was independently predictive of postoperative delirium in spinal deformity patients.<sup>81</sup>

Delirium risk can be determined with the AWOL stratification and can be derived from nursing assessment data.<sup>82</sup> The AWOL screen consists of age, ability to spell "world"

**Table 2.** Dementia Assessment Tools.

Name	Assessment Method	Pros/Cons
Mini-Mental Status Examination (MMSE) <sup>84</sup>	Questionnaire	<ul style="list-style-type: none"> <li>• Pros: 5- to 10-minute examination. Most commonly used test between clinicians to track cognition over time</li> <li>• Cons: It may cause false positives for those with little education or false negatives for those with high premorbid intellectual functioning. It may also be psychologically stressful to patients. MMSE also does not take into account educational and cultural differences</li> </ul>
Mini COG <sup>85</sup>	Three-part diagnostic test	<ul style="list-style-type: none"> <li>• Pros: Good validity and reliability. This 3-minute administration can detect cognitive impairment quickly during both routine visits and hospitalizations. Not largely influenced by language, culture, and education levels.</li> <li>• Cons: Cannot measure progression or extent of dementia. Patients who have visual impairments or difficulty with holding or using the pen or pencil will not be suitable for the test</li> </ul>
General Practitioner Assessment of Cognition (GPCOG) <sup>9</sup>	Two-stage method composed of cognitive assessment and informant questionnaire	<ul style="list-style-type: none"> <li>• Pros: Total administration is less than 5 minutes, does not require extensive training to administer, performs as well as MMSE and the AMT, good psychometric properties and time efficiency,<sup>78</sup> not largely influenced by education levels.</li> <li>• Cons: Little understanding on what is the impact of different cultures and languages to the test results. Patients who have visual impairments or difficulty with holding or using the pen or pencil will not be suitable for the test</li> </ul>
Abbreviated Mental Test (AMT) <sup>67</sup>	Questionnaire	<ul style="list-style-type: none"> <li>• Pros: 5-minute simple exam to perform and score</li> <li>• Cons: Limited validity data and cultural specific for 1970s elderly population. Not available for patients who have reduced GCS (or language barrier). Do not effectively test frontal/executive function<sup>86</sup></li> </ul>
Trail Making Test (TMT) <sup>35</sup>	Clinical testing	<ul style="list-style-type: none"> <li>• Pros: 5-minute exam composed of 2 parts for short screening purpose. First part (TMT-A) can be used to test cognitive processing speed, and second part (TMT-B) can be used to test executive functioning.<sup>87</sup></li> <li>• Cons: TMT-B is not suitable for patients who have visuospatial problems. TMT-B also appears to have limited capacity for detecting frontal executive dysfunction<sup>2</sup></li> </ul>
Clock Drawing Test <sup>61,88</sup>	Clinical testing	<ul style="list-style-type: none"> <li>• Pros: Fast screening tool, easy to administer. Better in detecting problem of executive functioning even when MMSE fails to identify.</li> <li>• Cons: Different scoring system and clock-drawing protocol</li> </ul>

backwards, orientation assessment, and nursing illness severity assessment.<sup>83</sup> Evaluation of baseline cognitive dysfunction is imperative in this group of patients as well. Several tools to evaluate dementia/cognition are outlined in Table 2. Patients with dementia oftentimes have issues with capacity, and this impacts the ability to obtain informed consent.<sup>89</sup> Assessment of social support and the caregiving environment can be incorporated into cognition workup as these factors are interrelated.

### *Intraoperative Parameters*

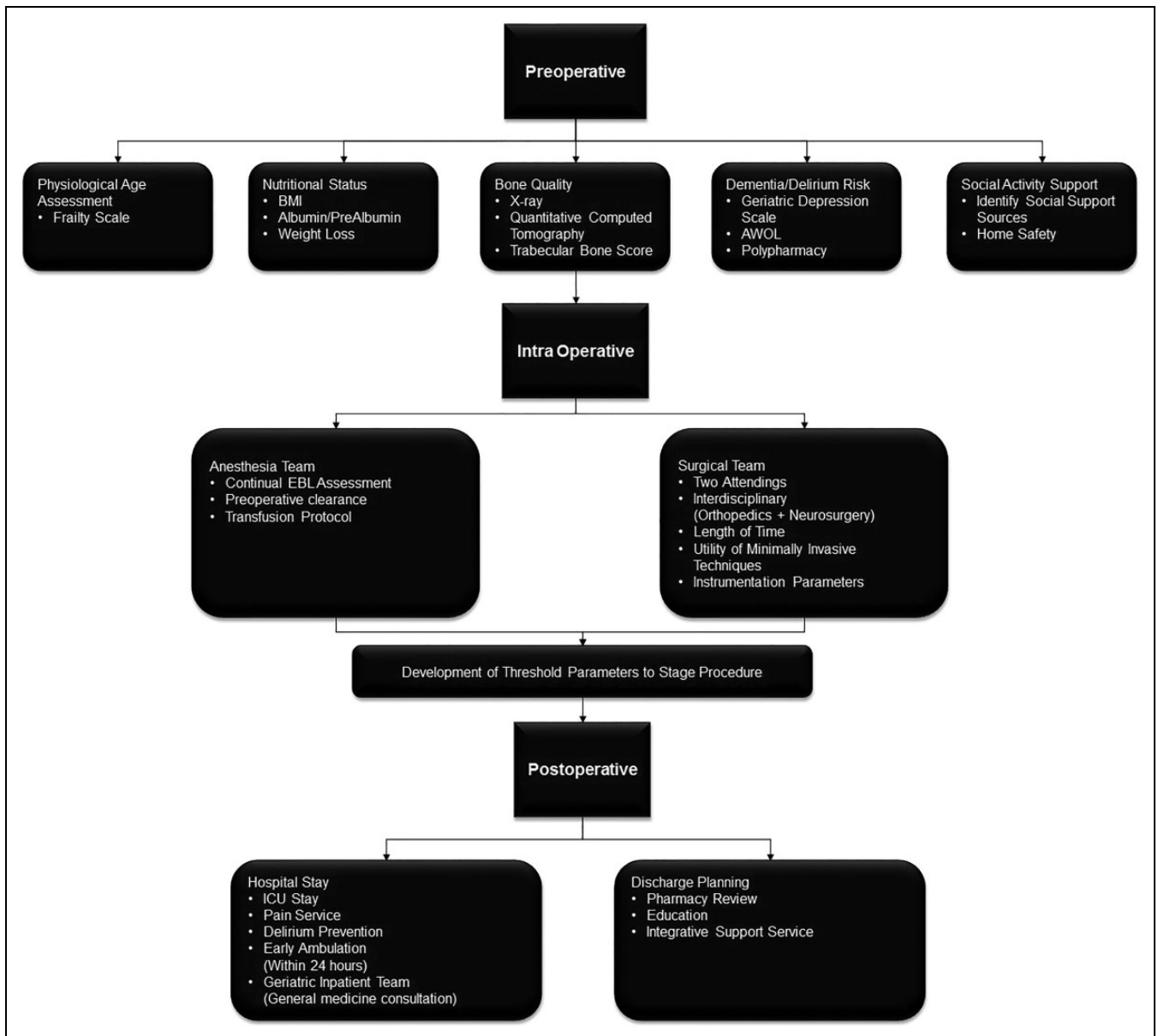
Many intraoperative parameters are associated with increased complication rates following spinal surgery. Extended operative time is a known factor correlating with postoperative complications in elderly patients undergoing lumbar spine surgery and patients with degenerative lumbar scoliosis.<sup>19,90,91</sup> In adult spinal deformity surgery, operative time was more predictive of surgical outcomes than operative complexity (ie, increased levels fused, presence of interbody fusions, osteotomies, and pelvic fixation).<sup>47</sup> Procedural time in excess of 309 minutes was associated with increased complication development for

patients with spinal arthrodesis analyzed from NSQIP between 2005 and 2010.<sup>21</sup> Oftentimes operative time and the levels of fusion are correlated. For patients aged 80 years or older, operative time increased with the amount of instrumentation. Instrumentation was associated with blood loss and delirium risk.<sup>20</sup> Fusion to the sacrum and osteotomies correlated have negative effects on recovery in the elderly population.<sup>92</sup>

Length of construct is a known factor associated with risk. Short fusion constructs (ie, 1 to 3 segments) for lumbar degenerative scoliosis can result in restoration of sagittal and coronal balance.<sup>87</sup> Whether or not an invasive technique is needed to achieve deformity correction is decided by the primary surgeon. Certain maneuvers such as 3-column osteotomy for adult spinal deformity is associated with a higher reoperation rate than patients who undergo standard surgical management.<sup>23</sup> These maneuvers may increase blood loss, which is another risk for complications as outlined previously.

### *Risk Prevention Strategies*

Decision-making for the planning of elderly adult deformity surgery is intricate. By understanding the risk factors for



**Figure 1.** Schematic of risk assessment and prevention strategies for adult spinal deformity patients during the perioperative period.

postoperative complications, spine surgeons can begin to alter their clinical practice. We summarize in Figure 1 preoperative, intraoperative, and postoperative risk prevention strategies. In addition to standard preoperative screening, evaluation of frailty, nutrition, bone density, and cognition is important in the elderly adult deformity patient. The American College of Surgeons (ACS) has developed a surgical risk calculator based on data from the NSQIP.<sup>14</sup> The ACS-NSQIP surgical risk calculator can be used for all specialties and in spine surgery underestimated complication occurrence.<sup>84</sup> Risk prediction in elderly spine patients requires multimodal methods.

Intraoperative factors such as procedural time and blood loss can be directly affected by the surgeon. For spinal deformity surgery, multidisciplinary team initiatives can reduce perioperative complications. A multidisciplinary preoperative

conference, dual attending surgeons, and a detailed protocol for coagulopathy/blood loss in the operating room are part of the Seattle spine team approach.<sup>48,93</sup> The presence of dual attending surgeons can decrease operative time. Utilization of the anesthesia team to implement a transfusion protocol reduced perioperative blood loss and coagulopathy. Furthermore, some rigid deformities require both an anterior and a posterior fusion or vertebral body resection which is done with the aid of an approach surgeon.<sup>94</sup> Coordination and communication is necessary for success of these large interdisciplinary surgical teams.

Another intraoperative factor is the use of minimally invasive spine surgery (MIS), which is becoming more widespread. In a comprehensive multicenter study, the use of MIS was associated with a reduction in construct length, blood loss, and

length of stay. Despite reduction in construct length, deformity correction was achieved based on radiographic criterion.<sup>95</sup> The rate of complications following adult spinal deformity surgery was lowest with minimally invasive techniques when compared to open or hybrid techniques.<sup>45</sup> “Old-old” patients (>75 years of age) had a similar complication profile compared to younger patients when MIS was used for lumbar interbody fusion.<sup>96</sup> A review of multiple studies demonstrated that rates of fusion and complications in the elderly individuals following MIS for deformity are acceptable.<sup>86,97,98</sup>

Besides the consideration of using MIS or traditional open techniques, the bone quality in elderly patients may warrant augmentation with polymethyl methacrylate or using longer screws with greater diameter.<sup>99</sup> Changing the pedicle screw trajectory can also impact the screw–bone interface.<sup>44</sup> The cortical bone trajectory for pedicle screws in osteoporotic bone provides better screw purchase than the traditional screw and has been used in elderly patients for this purpose.<sup>85,100</sup> While these construct parameters are determined by the surgeon, interdisciplinary communication between the surgical and anesthesia teams is necessary. Determination of threshold parameters to stop surgery and potentially finish in a staged fashion should be communicated beforehand.

Postoperatively, multidisciplinary care in the elderly improves outcomes. Interventions to encourage early ambulation may also lead to decreased length of stay, less perioperative complications, and improved functional outcomes.<sup>88</sup> Given the age-related changes in physiology and pharmacokinetics, pain management is particularly challenging in the elderly surgical patient. Adequate pain management can lead to earlier ambulation, earlier return of mental capacity, and shorter hospitalization. Multimodal adjuvant analgesia can help these patients manage pain.<sup>101</sup> However, caution must be used in the elderly individuals as polypharmacy predisposes to delirium. As previously discussed, delirium is a significant risk factor for postoperative complications. A multidisciplinary postoperative care team can help reduce delirium.<sup>75</sup> Spine surgeons should consider routine consultation of pain medicine and geriatricians for elderly adult deformity patients. For geriatric patients with hip fractures, discharge planning initiatives that maximize social support, ensure a safe discharge environment, and discuss advance care planning can help enhance quality of life.<sup>102</sup> The integration of a geriatrician on the multidisciplinary team doing the in-hospital stay significantly decreases the use of critical care services following deformity surgery.<sup>103</sup> Increasing age and critical care services are independent predictors of readmission for altered mental status for spinal deformity patients.<sup>104</sup>

## Conclusion

Elderly adult deformity patients have a greater prevalence of complicated outcomes which include longer hospitalization, reoperation, and mortality. As the population continues to age, the frequency of surgery for these patients will increase. Surgical risk assessment and prevention in these patients can lead

to improved outcomes and significantly impact surgical decision-making and patient counseling. In order to improve patient outcomes, assessing preoperative measures (ie, bone quality, dementia/delirium risk, and so on), intraoperative strategies (ie, reducing blood loss, proper communication between surgical and anesthesia teams, etc), and postoperative recovery (ie, early ambulation, pharmacy review, etc) can give patients with a spinal deformity better outcomes. By combining management principals from spine surgery and geriatric medicine, multidisciplinary perioperative strategies can be integrated into the spine surgeon’s armamentarium to reduce risk.


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