

TEAM APPROACH: SAFETY AND VALUE IN THE PRACTICE OF COMPLEX ADULT SPINAL SURGERY

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Abstract

» Surgical management of complex adult spinal deformities is of high risk, with a substantial risk of operative mortality.

» Current evidence shows that potential risk and morbidity resulting from surgery for complex spinal deformity may be minimized through risk-factor optimization.

» The multidisciplinary team care model includes neurosurgeons, orthopaedic surgeons, physiatrists, anesthesiologists, hospitalists, psychologists, physical therapists, specialized physician assistants, and nurses.

» The multidisciplinary care model mimics previously described integrated care pathways designed to offer a structured means of providing a comprehensive preoperative medical evaluation and evidence-based multimodal perioperative care.

» The role of each team member is illustrated in the case of a 66-year-old male patient with previous incomplete spinal cord injury, now presenting with Charcot spinal arthropathy and progressive vertebral-body destruction resulting in lumbar kyphosis.

Spinal reconstructive operations for adult spinal deformity are complex procedures that have been traditionally associated with substantial risk of perioperative morbidity and even mortality¹⁻¹¹. Despite these risks, the utilization of these procedures has increased substantially as studies have shown that patients derive notable improvement in their quality of life following surgery and have relatively poor results with nonoperative treatment^{12,13}. Given the lack of durable improvement with current nonoperative measures, it is paramount for surgeons to find ways to get patients safely through these complex operations to achieve the best possible clinical outcome without subjecting them to unnecessary surgical or medical risks that may result in

permanent harm. We believe that a team approach, engaging all of the relevant subspecialties in the pre-, intra-, and postoperative periods, is necessary for the optimal care of this complex patient population.

There are many factors regarding why a multidisciplinary team is essential to care for patients with complex adult spinal pathology, but the overarching reason is that it is unrealistic for a single surgeon to be able to adequately address all of the perioperative needs of a patient with spinal deformity to achieve optimal outcomes while mitigating risk appropriately. With a rapidly aging population, the pool of patients who might benefit from complex spinal reconstruction has not only increased in size but also has become sicker,

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often with multiple medical comorbidities that predispose these patients to perioperative complications^{1,6,14-16}. Preoperative medical “optimization” of these patients, targeting modifiable factors with interventions and determining which nonmodifiable factors put patients at risk, is critical to achieving a successful postoperative surgical outcome¹⁷⁻¹⁹; however, in most situations, a primary care physician providing “medical clearance” will have little-to-no understanding of the magnitude of the operative intervention proposed and the attendant perioperative risks. For example, patients receiving chronic anticoagulation therapy because of active cardiac conditions have increased risk of either thromboembolism or excessive bleeding. Since it is not unusual for these patients to lose a substantial amount of blood during surgery, they are carefully monitored by an anesthesiologist, a cardiologist, and 1 of the hospitalists on our team. In our experience, before implementation of the multidisciplinary model, these subspecialists (e.g., cardiology, pulmonology) may have been involved in the preoperative evaluation but communication between them and the surgeon was usually haphazard and indirect. Furthermore, they may or may not have been a part of the patient’s care during the postoperative period, which frequently resulted in less than optimal coordination between disciplines.

When it comes to mental health, preoperative assessment is limited to a few psychosocial predictors of poor postoperative outcomes. Many patients with spinal deformities have chronic pain disorders, associated psychological comorbidities, and lack of social or family support, which can affect their ability to cope with the spinal pathology and recover from a major operation^{20,21}.

There is also evidence that surgeons may entertain different ideas as to the most appropriate way to surgically correct any given adult spinal deformity, with varying opinions on level selection, approach, and even desired postoperative alignment²²⁻²⁵. These disparate surgical plans are shaped in part by sur-

geon experience, technical expertise, training background, institutional resources, and a lack of evidence-based standards to guide surgical treatment of even the most basic spinal pathologies, such as a single-level lumbar degenerative spondylolisthesis²⁶⁻²⁸. A team approach to surgical planning and decision-making may result in a decrease in the most basic errors and may lead to fewer reoperations and revisions and thus better outcomes¹⁷.

Intraoperatively, these cases are also difficult to manage from both a surgical and an anesthesia perspective, as the operations can be lengthy, sometimes taking place in a staged fashion over 2 days, and are frequently associated with high blood loss²⁹⁻³¹. The usual anesthetic agents often cannot be used because of the need for intraoperative neuromonitoring. There may be additional issues that complicate anesthesia care in patients with cervical or cervicothoracic pathology, such as a difficult airway or the inability to position the patient normally for surgery. Involvement of our anesthesia colleagues in the preoperative planning process may help with the anticipation of intraoperative challenges and may help to decrease surgical complications. From the surgical side, these operations can pose a mental and physical burden on surgeons who take on these challenging cases. A team-based approach involving 2 attending surgeons working together during complex spinal reconstruction may be beneficial to improve patient outcomes and decrease complication rates^{17,32-35}.

In this review, we present a clinical scenario describing the care of a patient requiring a complex spinal reconstruction and highlight the important aspects of preoperative, intraoperative, and postoperative work that can benefit from a team approach.

Clinical Scenario

Written patient consent was received for the publication of case details.

A 66-year-old man who uses a wheelchair and has a remote history of a cervical cord injury following a motor vehicle accident presents with progres-

sively worsening loss of strength and mobility as well as severe and occasionally uncontrollable back pain. At the time of the accident, in the early 2000s, the patient was treated with anterior cervical fusion, and he recovered partial motor strength in his arms and legs. He was able to perform basic activities of daily living, including transfers and limited ambulation with a walker; however, in the years leading up to the current appointment, he began to develop worsening sensation and pain that involved the lower extremities, hips, and back. His medical history is notable for cardiac ablation for treatment of atrial fibrillation, renal cell carcinoma treated with cryoablation, and hospitalization due to urosepsis, which happened approximately 1 month after the patient sustained a fall and began experiencing exacerbation of his low-to-mid-back symptomatology. He reports relief from daily pain, rated between 5 and 8 on a visual analog scale (VAS), when lying flat. Along with 50 mg of tramadol, the patient self-reports daily use of oral tetrahydrocannabinol (THC) and oral tobacco but reports that he does not smoke cigarettes. Comorbidities include medication-controlled hypertension (HTN), chronic obstructive pulmonary disease (COPD), sitagliptin-controlled diabetes mellitus, and Class-I obesity (body mass index [BMI] of 32.03 kg/m²). Outpatient evaluation of neurobehavioral status also revealed a major depressive disorder, anxiety, and mild cognitive impairment, as evidenced by the patient’s Montreal Cognitive Assessment (MoCA)³⁶ score of 24 of 30.

On examination, he has diffuse degenerative arthritis involving his shoulders and hands bilaterally. The distal lower extremities are also cool to the touch and swollen. Bilateral deltoid strength is rated as 4 of 5; left biceps, triceps, grip, and intrinsic muscle strength is 4 of 5; and right biceps, triceps, grip, and intrinsic muscle strength is 3 of 5. Bilateral hip flexor strength is rated as 3 of 5; and bilateral knee extensor, dorsiflexor, plantar flexor, and extensor hallucis longus strength is 4 of 5. The patient has severely diminished sensation bilaterally in the



Fig. 1

Preoperative images including a CT scout view (**Fig. 1-A**), showing a previous anterior cervical fusion with evidence of adjacent-segment disease, and lumbar radiographs (**Figs. 1-B and 1-C**), showing an L1-L2 Charcot joint with a focal kyphotic lumbar sagittal-plane deformity.

lower extremities distal to a dermatome located at approximately T12.

A computed tomography (CT) scout view of the entire spine (Fig. 1-A) and lumbar radiographs (Figs. 1-B and 1-C) show a previous anterior cervical fusion with evidence of adjacent-segment disease as well as an L1-L2 Charcot joint with a focal kyphotic lumbar sagittal-plane deformity. Progressive radiographs over the past 3 years reveal increased destruction of both L1 and L2, typically characteristic of a progressive Charcot spinal arthropathy. Erythrocyte sedimentation rate (ESR), C-reactive protein (CRP) levels, and other laboratory markers for infection have all been normal.

Team Approach

The use of a multidisciplinary team has become a more common approach to the management of adult spinal deformity since seminal reports demonstrated dramatic improvements in safety using such an approach^{17,19}. Three elements have been described as most important to its success: teamwork, communication, and a climate of safety³⁷. With our approach, this translates to standard work for each team member, a live conference for face-to-face communication of the team, and the use of lean management principles to mistake-proof processes, which provides successive safety checks and “stop the line” opportunities when

a team member identifies a serious safety concern.

In this model, the team is able to anticipate and manage complex issues requiring substantial nonsurgical expertise. In the case of elective surgery for spinal deformity, we utilize a multidisciplinary team at all phases of care. The mix of specialists in addition to neurosurgeons and orthopaedic spine surgeons includes psychologists, physiatrists, and specialists in hospital medicine, pain management, anesthesia, nursing, and physical therapy. Every patient considered for elective complex spine surgery undergoes a preoperative psychological evaluation, measurements of function, and evaluation for social

barriers to function. Before a final decision is made to proceed with surgery, a live multidisciplinary conference is held. Issues raised by any team member are addressed by the group before proceeding with a treatment recommendation.

The Seattle Spine Team previously evaluated outcomes associated with the implementation of this systematic complex spine surgery care protocol. The postoperative outcomes of 71 patients who underwent elective, nonemergency complex spine surgery involving ≥ 6 levels of vertebral fusion before protocol implementation (between 2008 and 2010) were compared with those of 69 patients who underwent complex spine surgery after protocol implementation (2010 to 2012). The evaluation showed that the protocol was associated with a reduction in postoperative complications, including cardiovascular events, infections, and implant failure within 30 days of surgery¹⁸.

In the clinical scenario described above, the patient was treated by a multidisciplinary group of providers who make up the Seattle Spine Team at Virginia Mason Medical Center. Patient data, including medical history and results of his psychological screening, were presented to the group during a multidisciplinary conference in October 2018. After evaluating comorbidities, assessing risk, and requesting additional testing, the patient was cleared for surgery by the team. Key elements of the patient's pathway are described in more detail here.

Medical, Rehabilitative, and Psychological Considerations

Individuals with spinal deformity do not become uniformly disabled as they age. Patients present for consideration of surgery most frequently not for progressive deformity, but rather seeking relief of pain and disability³⁸. Because outcomes related to pain and disability in spine surgery populations depend heavily on medical, lifestyle, and psychosocial variables, addressing these areas as part of a treatment plan for spinal deformity is critical.

Psychologist

The literature contains numerous reports on the clinical and economic impact of psychological and psychosocial vulnerability on short and long-term outcomes after spine surgery. Depression and anxiety are the best studied, but other conditions and issues, such as substance use disorders, cognitive impairment, and social challenges, have also been shown to influence surgical outcomes and patient satisfaction with care. For example, a previous study found that patients with depression and anxiety at the time of surgery were more likely to report a failure to improve functionally, have improvement in pain, or return to work³⁹. Similarly, a recent multi-institutional study in Washington State found that patient-level variables such as lower levels of functional disability and insurance status (Medicaid or Workers' Compensation) had a greater impact on patient outcomes than did surgical invasiveness, surgeon specialty, or hospital type⁴⁰.

As part of the clinical pathway for the consideration of complex spinal deformity surgery at Virginia Mason, each patient is scheduled to undergo a comprehensive preoperative assessment of their psychological, psychosocial, and cognitive-function status and their expectations. Diagnostic recommendation is made by the psychologist after a neurobehavioral status examination and administration of several standardized tests, including the MoCA³⁶, the Patient Health Questionnaire (PHQ)-9⁴¹, and the Generalized Anxiety Disorder (GAD) 7-item test⁴². An in-depth discussion about treatment expectations, caregiver support, and psychosocial circumstances is also conducted by the psychologist during this 3-hour visit. At the end of the standardized preoperative psychological assessment, the patient's psychological and psychosocial comorbidities are communicated to the team. In certain instances, such as the presence of suicidal ideations, patients are not cleared for surgery while they receive treatment from a behavioral health provider.

The psychological assessment of the patient described in the clinical sce-

nario resulted in a diagnosis of a major depressive disorder, anxiety, and mild cognitive impairment, as evidenced by the patient's MoCA score of 24 of 30. These results were shared with the treatment team at the multidisciplinary conference to guide the treatment plan, given the likelihood of a somewhat slower recovery accompanied by higher expenditures.

Specialized Complex Spine Nurse

Recognizing that the patient was diagnosed with mild cognitive impairment, the multidisciplinary team recommended the patient's participation in a structured preoperative education class, which is not meant to replace the discussion between the patient and the physician but rather to allow for additional educational instruction to take place. Studies have shown that patients who have limited understanding of surgical risks are more likely to be dissatisfied and file legal claims⁴³⁻⁴⁶, while those who receive additional preoperative education report increased patient and family-member satisfaction, fewer pain medication requests, and reduced hospital length of stay^{47,48}. Furthermore, population-based studies have shown a high prevalence of limited health literacy in the United States and worldwide. Notably, those studies also demonstrated an association between limited health literacy and poor outcomes⁴³⁻⁴⁸. The goal of preoperative health education at our institution is to ensure that patients who are considering complex spinal reconstructive surgery are well informed before their procedure.

The 2-hour preoperative education class, led by a specialized spine nurse, combines verbal, written, and audiovisual content, with time dedicated for questions at the end. All patients and their caregivers attending the class receive a standardized binder with printed educational materials for review in preparation for surgery and to assist in postoperative care, including current guidelines and common indications for inferior vena cava (IVC) filter placement and management of

postoperative pain. The patient described in the clinical scenario attended the spine class with his caregiver. In addition to verbal instructions, the patient was given the binder described above.

Hospitalist

The impacts of medical comorbidities such as smoking, poor nutrition, and obesity have been well described⁴⁹. Frailty, a concept that incorporates cardiopulmonary, metabolic, and functional measures, has been shown to have an important impact on the incidence of major complications, surgical infections, length of stay, and 30-day mortality among patients undergoing surgery for degenerative spine disease⁵⁰.

In the clinical scenario described above, the patient required an inpatient hospitalist to assist the spine team on daily rounds. The presence of a hospi-

talist on the complex spine conference committee led to advance notice and important transfer of information between hospitalists so that patient care was well coordinated.

Anesthesiologists

Each patient who is scheduled for complex spine surgery is discussed in our monthly multidisciplinary complex spine conference, which is attended by a variety of medical professionals who provide specialized input. Members include a dedicated complex spine anesthesia team of 7 faculty anesthesiologists and 3 certified registered nurse anesthetists. The anesthesia team discusses in detail the proposed surgical correction as stated by the surgeon, and reviews the preoperative, intraoperative, and postoperative medical issues related to the patient.

At Virginia Mason Medical Center, standard work protocols have been

created. These pathways, specific for complex spine candidates, help ensure that each patient has the appropriate work-up for their proposed surgery. Assignments are shared with respective members of the complex spine anesthesia team approximately 2 weeks in advance. Each member, including our anesthesia technicians, is invested in this pathway in preparation for surgery.

All patients with normal preoperative coagulation and hematological panels are assigned 2 units of packed red blood cells and 1 unit of thawed plasma. Recognizing this as a potential source of waste, we have improved our coordination with the on-site blood bank through the use of various tools and communication technologies. At the same time, we also created recommendations for anticipated blood loss and product management for patients with complex adult spinal deformity

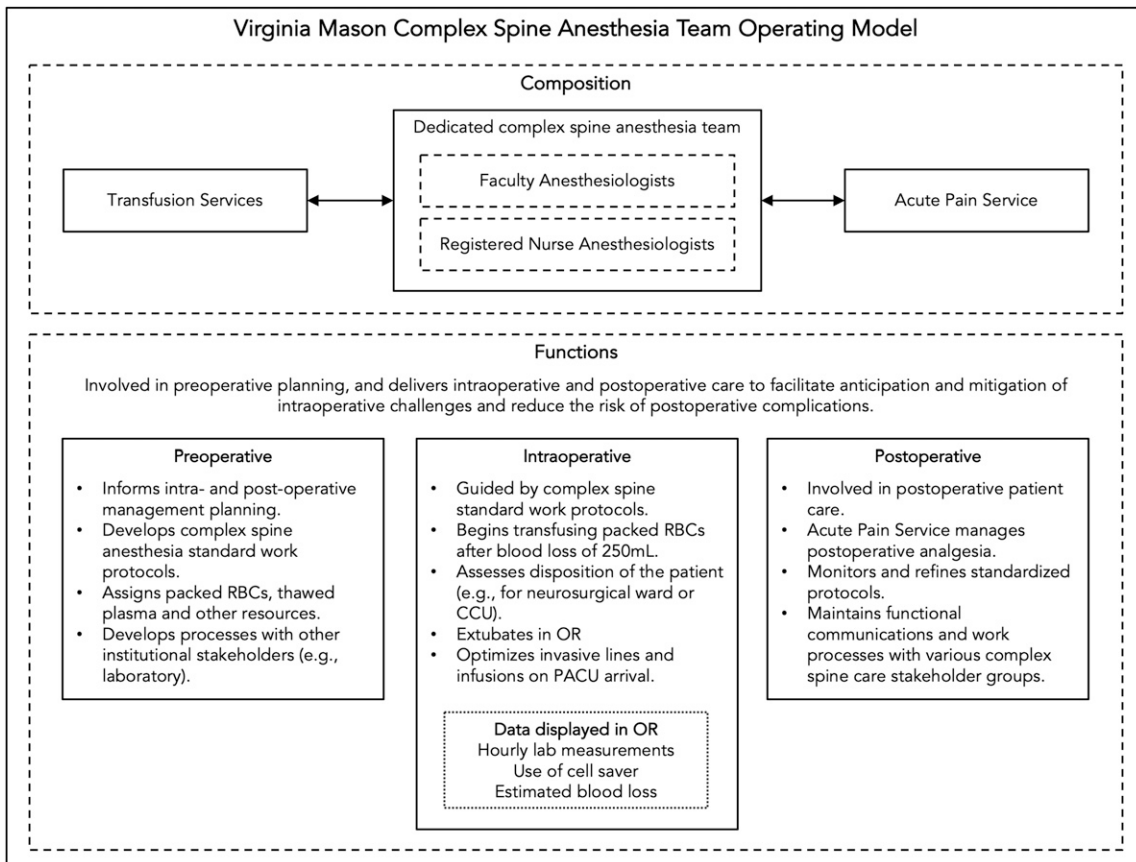


Fig. 2

The anesthesia team's operating model, displaying composition and functions. RBCs = red blood cells, CCU = critical care unit, OR = operating room, and PACU = post-anesthesia care unit; Cell Saver (Haemonetics).

undergoing planned staged operations, striking a fine balance between product availability and reduced waste. Typically, our anesthesia team begins transfusing packed red blood cells after a patient blood loss of 250 mL¹⁷. Laboratory measurements (including arterial blood gas, hematocrit, platelet count, fibrinogen level, D-dimer, prothrombin time [PTT], and international normalized ratio [INR]) are assessed hourly and posted on a visible whiteboard so that all members in the operating suite may view this information. The large laboratory board also tracks the use of cell salvage and estimated blood loss.

The anesthesiologist and surgeon together decide the disposition of each patient: the spine floor or critical care unit. Extubation is routinely attempted in the operating room, and invasive lines and infusions such as ketamine are optimized upon post-anesthesia care

unit (PACU) arrival. Figure 2 provides an overview of the anesthesia team's operating model.

Pain Management Specialist

All patients undergoing the major complex spine pathway have their analgesia managed postoperatively by the Acute Pain Service (APS), which is run by the Department of Anesthesiology. Members of this service also attend the multidisciplinary complex spine conference and have the ability to delay surgery should there be any concerns. Preoperatively, the APS team reviews the medical and surgical history of each patient in order to develop its recommendations for an intraoperative and postoperative plan. These recommendations include but are not limited to a ketamine infusion, a preoperative multimodal regimen, long-acting enteral opioids, and other medication adjuncts.

Surgical Team

The performance, morale, and sustainability of the surgical team are facilitated by appropriate, modern leadership⁵¹. Surgical leaders are value-driven and shape a positive team culture. They facilitate intrinsic motivation and augment performance with 3 core sets of leadership behaviors: (1) building relationships, (2) providing individuals with autonomy, and (3) reinforcing their competence⁵². Cooperative, highly capable spine-surgery teams with authentic leaders, clear goals and roles, and a focus on continuous improvement perform effectively in delivering high-quality, high-value patient care^{51,53-55}.

Two Attending Spine Surgeons

The Seattle Spine Team Approach includes the use of 2 attending spine surgeons as a means of reducing intra- and postoperative complications¹⁷. While the

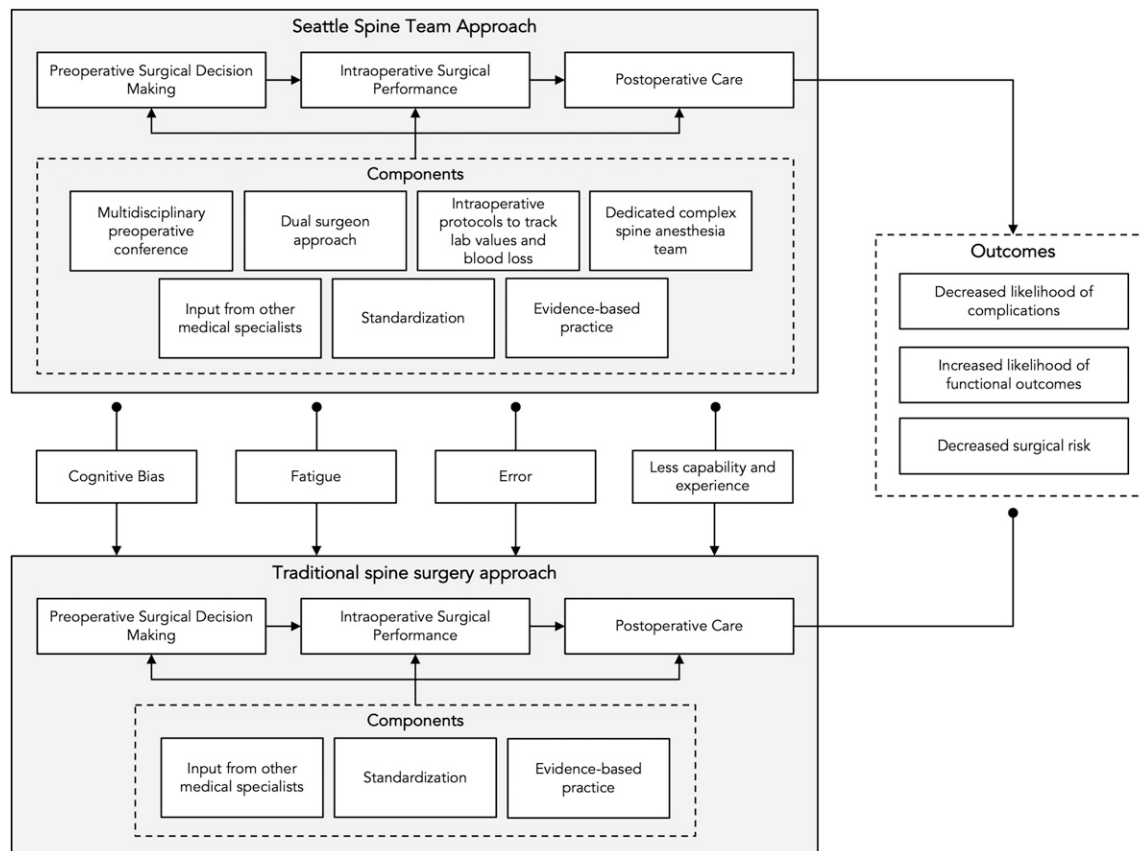


Fig. 3 A conceptual model comparing the Seattle Spine Team Approach with a traditional surgical practice approach. The Seattle Spine Team Approach is designed to mitigate risk and optimize patient outcomes.



Fig. 4
Postoperative standing lateral radiograph demonstrating spinal correction in the patient.

classic model of the operating room identified the surgeon as the “captain of the ship,” this newer approach envisions a team of dedicated and invested surgeons working together to achieve a complex goal. It should be noted that, in the dual-surgeon practice implemented at our institution for complex and high-risk procedures, the roles of the attending surgeons are clearly defined both on the consent form and in the operating room. One of the surgeons is designated as primary, while the second is listed as either a co-surgeon or assistant surgeon on the team. When faced with a case such as that of the patient in the clinical scenario, with a Charcot spine and worsening kyphosis, this type of surgical team is able to engage in an extensive preoperative surgical-planning discussion, develop a plan of care playing on the strengths of each individual surgeon’s expertise, and identify portions of the case that might require a change in the preoperative plan. The use of a dedicated team who has worked together through past difficult cases allows the team to take strategic risks for potential greater benefit with less fear of individual failure. A co-surgeon is also able to minimize the so-called “fog of war” effect⁵⁶, which may cloud a single surgeon’s judgment when an intraoperative complication arises and also help reduce the psychological load borne by any single surgeon during and after especially stressful cases. The benefit of

2-surgeon teams in reducing operative times and blood loss has been demonstrated repeatedly in studies of complex spine surgery, and we propose that these improvements are multifactorial in nature and encompass both physical gains in speed as well as reductions in psychological burden and resultant poor decision-making^{34,57-60}. Figure 3 provides a comparison between the Seattle Spine Team Approach and a more traditional approach to spine surgery.

In this circumstance, the surgical team had discussed the case at the multidisciplinary conference and had recommended starting with a posterior approach, placing pedicle screws from T10 through the pelvis, as well as performing vertebroplasty cement augmentation of the T9, T10, T11, T12, and L3 vertebral bodies. Osteotomies were performed across the T11 through L3 levels to reduce the kyphosis and restore a normal thoracolumbar alignment. Four 5.5-mm cobalt-chromium rods and 2 large packets of bone morphogenetic protein (BMP) were utilized on the T10-S1 posterolateral fusion. The upper levels were instrumented to provide additional structural support and reduce the risk of proximal junctional kyphosis, while the T12 and L3 levels were augmented to reduce the risk of cage subsidence. The second stage of the procedure was performed the following day and utilized a minimally invasive lateral approach to a 2-level corpectomy and debridement of L1 and L2 followed by the placement of a large expandable titanium implant to provide anterior structural support for the area of previous collapse and kyphosis. This combined procedure capitalized on the individual strengths of each member of the surgical team, utilizing such varied techniques as iliac fixation, vertebral cement augmentation, and transposas minimally invasive lumbar approaches. Postoperative radiographs (Figs. 4 and 5) demonstrate the spinal correction.

Conclusions

To achieve safe and high-quality complex spine care, the health-care team must function in a highly integrated

way. Organizational integration is key to the delivery of surgical and medical excellence⁶¹. The success of a surgical team is also dependent on factors external to the organization. In our experience, practice performance is influenced by (1) contributions to the peer-reviewed academic literature, (2) cultivating professional networks, (3) maintaining a presence at conferences and meetings, and (4) cooperating appropriately with other hospitals.

Given the numerous challenges that exist in caring for patients with adult spinal deformities, and the amount of provider and institutional variability that exists worldwide in the delivery of this care, the potential for error is high when 1 provider has sole responsibility for providing this care. Given this, a team approach to the care of patients with adult spinal deformity is critical and should become standard in the care of these patients in the pre-, intra-, and postoperative settings.

Team-based approaches are being utilized in several areas of medicine and

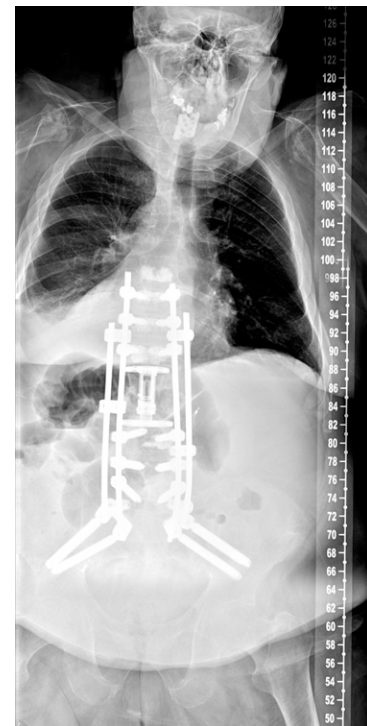


Fig. 5
Postoperative standing anteroposterior radiograph of the entire spine in the same patient as shown in Figure 4.

have been shown to have many advantages over individual decision-making or a single individual performing a challenging task and are effective in reducing complication rates^{62,63}. Given the inherent complexity of treating patients with complex adult spinal deformities, input from multiple surgical and nonsurgical stakeholders during the care of these patients may help to minimize variability in the decision-making process and, in this manner, improve patient care¹⁸.

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