Assessment of Surgical Treatment Strategies for Moderate to Severe Cervical Spinal Deformity Reveals Marked Variation in Approaches, Osteotomies, and Fusion Levels

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■ OBJECTIVE: **Although previous reports suggest that surgery can improve the pain and disability of cervical spinal deformity (CSD), techniques are not standardized. Our objective was to assess for consensus on recommended surgical plans for CSD treatment.**

■ METHODS: **Eighteen CSD cases were assembled, including a clinical vignette, cervical imaging (radiography, computed tomography/magnetic resonance imaging), and full-length standing radiography. Fourteen deformity surgeons (10 orthopedic, 4 neurosurgery) were queried regarding recommended surgical plans.**

■ RESULTS: **There was marked variation in treatment plans across all deformity types. Even for the least complex deformities (moderate midcervical apex kyphosis), there was lack of agreement on approach (50% combined anterior-posterior, 25% anterior only, 25% posterior only), number of anterior (range, 2—6) and posterior (range, 4—16) fusion levels, and types of osteotomies. As the kyphosis apex moved caudally (cervical-thoracic junction/upper thoracic spine) and for cases with chin-on-chest kyphosis, >80% of surgeons agreed on a posterior-only approach and >70% recommended a pedicle subtraction osteotomy or vertebral column resection, but the range in number of anterior (4—8) and posterior (4—27) fusion levels was exceptionally broad. Cases of cervical/cervical-thoracic scoliosis had the least agreement for approach (48% posterior only, 33% combined anterior-posterior, 17% anterior-posterior-anterior or posterior-anterior-posterior, 2% anterior only) and had broad variation in the number of anterior (2—5) and posterior (6—19) fusion levels, and recommended osteotomies (41% pedicle subtraction osteotomy/vertebral column resection).**

■ CONCLUSIONS: **Among a panel of deformity surgeons, there was marked lack of consensus on recommended surgical approach, osteotomies, and fusion levels for CSD. Further study is warranted to assess whether specific surgical treatment approaches are associated with better outcomes.**

INTRODUCTION

Although cervical spinal deformity (CSD) can have a profound impact, including pain, disability, and neurologic compromise, there are relatively few reports that detail its surgical treatment.[1-3] Early reports focused on small series of

Key words
- Cervical
- Deformity
- Fusion
- Kyphosis
- Osteotomy
- Spine
- Surgery

Abbreviations and Acronyms
CSD: Cervical spinal deformity
PSO: Pedicle subtraction osteotomy
SD: Standard deviation
SRS: Scoliosis Research Society
VCR: Vertebral column resection

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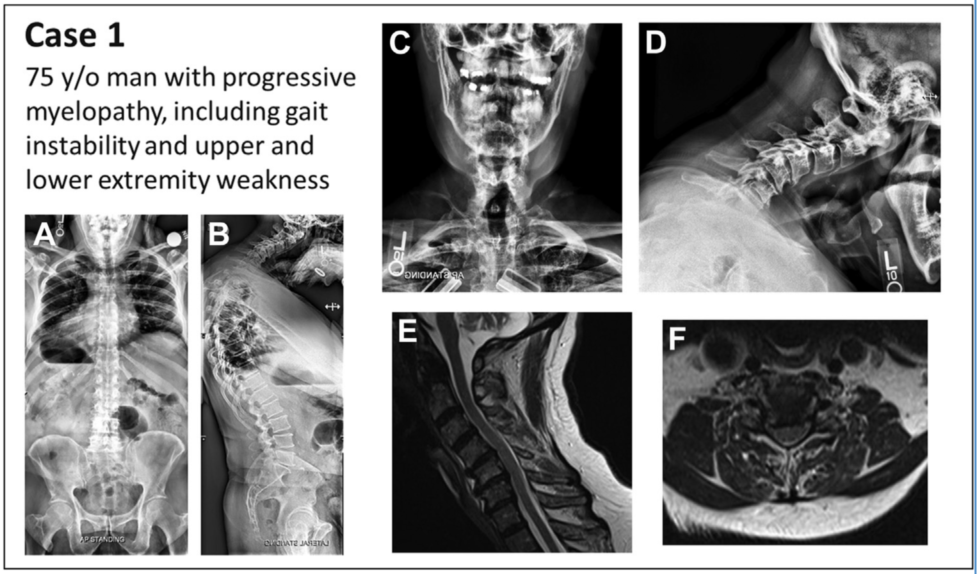

Figure 1. Example case presentation. Each of 18 cases were presented with a brief clinical vignette and imaging studies. Images shown for this case are posteroanterior (**A**) and lateral (**B**) full-length satanding spine radiographs, posteroanterior (**C**) and lateral (**D**) cervical radiographs, and midsagittal section of a T2-weighted magnetic resonance image of the cervical spine (**E**) with corresponding axial T2-weighted section at the level of C5-C6 (**F**). y/o, year-old.

patients who were treated with what were considered high-risk procedures and often had high rates of significant complications.[4-6] Through continued improvements in anesthesia and critical care and marked advancements in surgical techniques and instrumentation over recent decades, there has been a renewed interest in addressing these often challenging deformities.[2,3,7-28]

A broad range of underlying diseases may contribute to the development of CSD, including spondylosis, inflammatory arthropathies, trauma, infection, neoplasm, congenital anomalies, and neuromuscular conditions.[1,2,12] The cause of CSD may also be iatrogenic, resulting directly or indirectly from the effects of previous procedures or surgical treatments.[10,20,29,30] Collectively, these factors can produce a variety of deformities that most commonly include varying combinations of kyphosis, listhesis, and scoliosis. These deformities may prompt patients to seek medical attention for several reasons, including neck pain, radicular pain or weakness, myelopathy, and impaired function. Impaired function may include difficulty holding the head upright, which can compromise the ability to swallow and the fundamental ability to maintain horizontal gaze to ambulate safely and interact socially.[31]

Management of the patient with CSD is highly dependent on the presentation. Patients with primarily neck pain, in the absence of significant or progressive neurologic or severe functional impairment, may benefit from at least a trial of nonoperative treatments, which may include physical therapy, nonsteroidal anti-inflammatory medications, muscle relaxers, and possibly consultation with a pain management specialist. For the subset of patients with CSD who have exhausted nonoperative measures without adequate benefit or who present with concerning neurologic compromise or functional impairment, surgical treatment may be warranted.

Strategies for the surgical treatment of CSD are often complex and are not standardized. Surgical approaches may be anterior, posterior, or combined (eg, anterior-posterior, posterior-anterior, posterior-anterior-posterior). A variety of soft tissue releases and osteotomies, ranging from simple facet release to vertebral column resection (VCR), may be applied for decompression and deformity correction.[8] To facilitate deformity correction, stabilization, and arthrodesis, an increasing array of anterior and posterior spinal instrumentation may be used, including anterior cervical plates and cages and posterior screws, hooks, rods, wires, and plates. The number of vertebral levels, anterior and posterior, that may warrant instrumentation and arthrodesis is also variable. Although there are no previous reports that have focused on differences in surgical approach(es), use of osteotomies, and extent of instrumentation and fusion for the surgical treatment of patients with CSD, given the wide range of options and the lack of standardization, it is likely that there is at least some degree of variation among surgeons. These variations may have significant impact on complication risk, patient outcomes, and cost. Defining these differences and assessing their impact may prove valuable for surgical planning, improving the safety of care, optimizing patient outcomes, and reducing cost. For example, Shamji et al.[32] and Mohanty et al.[33] have shown that variations in surgical approach for the treatment of cervical spondylotic myelopathy in the context of cervical sagittal alignment can significantly affect neurologic recovery among kyphotic patients.

As a first step toward defining variation in the surgical treatment of patients with CSD, in the present study, we sought to assess whether there is agreement on recommended surgical plans for the treatment of a series of patients with moderate to severe cervical deformity based on a survey of experienced spinal deformity surgeons.

METHODS

Case-Based Survey

Eighteen cases of CSD, ranging from moderate to severe deformity and representative of the general range of cervical/cervical-thoracic deformities, were assembled and prepared in an electronic file for review by a panel of spine deformity surgeons (Figure 1). For each case, a brief clinical vignette was included that provided the patient age, gender, and primary presenting complaints. Representative imaging was also provided for each case, including cervical radiographs, cervical/cervical-thoracic computed tomography or magnetic resonance imaging, and full-length standing spine radiographs. Specific images of computed tomography and magnetic resonance imaging studies were selected to show the relevant disease. Immediately after presentation of each case, a series of 4 questions was provided to collect information on recommended surgical treatment plans, including use of preoperative traction and surgical approach(es). In addition, specific surgical details were collected for the anterior or posterior approaches, including the uppermost instrumented vertebra, lowermost instrumented vertebra, and levels of decompression, soft tissue releases, and osteotomies. The number of fusion levels was defined as the number of vertebra spanning the operation.

To help standardize responses, surgeons were requested to specify any recommended soft tissue releases and osteotomies for each case based on a recently published standardized nomenclature.[8] This nomenclature includes 7 anatomic grades of increasing extent of bone/soft tissue resection and destabilization. The 7 grades are as follows: partial facet joint resection (grade 1), complete facet joint resection/Ponte osteotomy (grade 2), partial or complete corpectomy (grade 3), complete uncovertebral joint resection to transverse foramen (grade 4), opening wedge osteotomy (grade 5), closing wedge osteotomy or pedicle subtraction osteotomy (PSO) (grade 6), and complete VCR (grade 7). An artist's illustration and description of this nomenclature were provided in the survey file for each reviewer.[8] Although reviewers were encouraged to use this nomenclature, common terminology for some of the soft tissue releases/osteotomies (eg, anterior cervical discectomy and cervical corpectomy) were also provided in the survey questions to facilitate data collection for those not so familiar with the nomenclature (Figure 2).

Surgeon Panel

A panel of 14 spine deformity surgeons was assembled from an active research study group. To collect demographics and experience levels for these surgeons, a series of questions were included at the beginning of the case-based survey. Information collected included whether the surgeon was trained as an orthopedic surgeon or neurosurgeon, number of years in practice, approximate percentage of practice that involves the cervical spine, approximate number of instrumented cervical cases performed annually, and approximate number of cervical deformity cases performed annually. Each member of the panel completed the review of 18 CSD cases independently and provided recommended surgery plans.

1. Would you perform pre-op traction? __ no __ yes

2. Please indicate surgical approach(es) and order:
_ ant only _ post only _ ant-post _ post-ant
_ post-ant-post _ ant-post-ant

3. For the anterior procedure(s) (if applicable):
-include discetomies? __ no __ yes (levels ____)
-include corpectomy? __ no __ yes (levels ____)
-include osteotomies? __ no __ yes (specify all below)
-osteotomy type and level(s) ____________________
-osteotomy type and level(s) ____________________
-osteotomy type and level(s) ____________________
-include plating? __ no __ yes (levels ____)

4. For the posterior procedure(s) (if applicable):
-include instrumentation? __ no __ yes (UIV __ LIV __)
-include laminectomy? __ no __ yes (levels ____)
-include osteotomies? __ no __ yes (specify all below)
-osteotomy type and level(s) ____________________
-osteotomy type and level(s) ____________________
-osteotomy type and level(s) ____________________

Figure 2. Series of 4 questions that were posed for each of the case presentations to collect information on recommended surgical. Ant, anterior; LIV, lowermost instrumented vertebra; post, posterior; UIV, uppermost instrumented vertebra.

Data Analysis

Demographic and experience level for surgeons in the survey panel were tabulated and summarized. Plans were compared across surgeons and by deformity type. For the purposes of the present study, deformities were categorized into one of 5 groups: 1) moderate midcervical apex kyphosis, 2) cervical kyphosis with apex at the cervical-thoracic junction, 3) chin-on-chest cervical kyphosis, 4) mild cervical kyphosis with midthoracic kyphosis, and 5) cervical/cervical-thoracic scoliosis. The surgical approach(es), anterior and posterior surgical levels, and recommended soft tissue releases and osteotomies were summarized for cases within each of these groups with attention to variations in treatment approaches across the panel of surgeons. The distribution of approaches recommended for each type of deformity was calculated as follows. First, for each case, the percentage of surgeons recommending each approach (anterior, posterior, combined anterior-posterior/posterior-anterior, or 540°) was calculated. Next, the average percent for each approach across the cases was calculated, and these average percentages are presented in the results. This calculation approach enables a combined assessment across the surgeons and cases.

Table 1. Summary of Recommended Approach(es), Number of Anterior and Posterior Levels to be Operated, and Osteotomies Based on a Survey of 14 Spine Deformity Surgeons and a Series of 18 Moderate to Severe Adult Cervical Deformity Cases

Deformity Type	Approach (%)	Preoperative Traction	Anterior Levels, Mean (Range)	Posterior Levels, Mean (Range)	Osteotomies
Moderate midcervical apex kyphosis (n = 8)	Anterior 25 Posterior 25 Anterior-posterior 50	For 4 cases (50%) at least 1 surgeon recommended preoperative traction (range, 1–8)	4.0 (2–6)	8.2 (4–16)	Most recommended facet releases and Ponte osteotomies (grades 1 and 2) 3 surgeons recommended PSO (grade 6) in C/T spine
Cervical kyphosis with apex at C/T-junction or upper T spine (n = 4)	Posterior 86 Anterior-posterior 14	Preoperative traction only recommended by 1 surgeon (7%) for 1 case	4.7 (4–8)	13.9 (7–19)	78% recommended PSO (grade 6) or VCR (grade 7) in C/T spine
Chin-on-chest cervical kyphosis (n = 2)	Posterior 82 Anterior-posterior 15 540° 3*	Preoperative traction recommended for each case by 7% and 50% of surgeons, respectively	4.5 (4–5)	13.2 (7–27)	72% recommended PSO (grade 6) or VCR (grade 7) in C/T spine 2 surgeons recommended PSO (grade 6) in L spine
Mild cervical kyphosis with midthoracic kyphosis (n = 2)	Anterior 11 Posterior 64 Anterior-posterior 25	Preoperative traction not recommended by any of the surgeons for either case	5.5 (2–8)	12.8 (4–22)	43% recommended PSO (grade 6) or VCR (grade 7) in C/T spine
Cervical/cervical-thoracic scoliosis (n = 2)	Anterior 2 Posterior 48 Anterior-posterior 33 540° 17	Preoperative traction recommended for each case by 21% and 36% of surgeons, respectively	3.3 (2–5)	11.7 (6–19)	41% recommended PSO (grade 6) or VCR (grade 7) in C/T spine

PSO, pedicle subtraction osteotomy; C, cervical; T, thoracic; VCR: vertebral column resection; L, lumbar.
*540° refers to anterior-posterior-anterior or posterior-anterior-posterior approaches.

RESULTS

Surgeon Panel

The panel of 14 surgeons who completed the study survey included 10 orthopedic surgeons and 4 neurosurgeons. The group had a mean of 10.6 years in practice (standard deviation [SD] = 5.3 years; range, 5–22 years) and had a practice that was on average 27.2% involving the cervical spine (SD = 13.9%; range, 15%–60%). The group performed on average 79.5 instrumented cervical spine cases per year (SD = 61.7; range, 30–250), and this included on average 20 (SD = 20; range, 12–69) cervical deformity cases per year.

Study Cases and Variation in Recommended Treatment Plans

The panel of 18 study cases included 8 with moderate midcervical apex kyphosis, 4 with cervical kyphosis with apex at the cervical-thoracic junction, and 2 each with chin-on-chest cervical kyphosis, mild cervical kyphosis with greater midthoracic kyphosis, or cervical/cervical-thoracic scoliosis. The variation in treatment approach, use of preoperative traction, anterior and posterior spinal fusion levels, and recommended osteotomies by deformity type are summarized in Table 1. There was marked variation in treatment plans across all deformity types. Even for the least complex deformities (moderate midcervical apex kyphosis), there was lack of agreement on approach (50% combined anterior-posterior, 25%, anterior only, 25% posterior only), number of anterior (range, 2–6) and posterior (range, 4–16) fusion levels, and types of osteotomies. Preoperative traction was recommended for 4 (50%) of the cases, and for each of these cases, the number of surgeons that recommended its use ranged from 1 to 8. Most surgeons favored the use of facet releases (grade 1) and Ponte osteotomies (grade 2), and 3-column osteotomies were included in the surgical plan by 3 surgeons. An example case presentation and summary of surgical treatment strategies for a moderate midcervical apex kyphosis are shown in Figure 3 (case 16).

As the kyphosis apex moved caudally (cervical-thoracic junction/upper thoracic spine) and for cases with chin-on-chest kyphosis, more than 80% of surgeons agreed on a posterior-only approach and more than 70% recommended a PSO (grade 6) or VCR (grade 7), but the range in number of anterior (4–8) and posterior (4–27) fusion levels was exceptionally broad (Table 1). Example case presentations and summaries of surgical treatment strategies for a cervical kyphosis with apex at the cervical-thoracic junction and for a chin-on-chest cervical kyphosis are shown in Figures 4 (case 6) and 5 (case 2), respectively.

For cases with relatively mild cervical kyphosis associated with a greater degree of thoracic kyphosis, most surgeons (64%) recommended a posterior-only approach and 25% recommended a combined anterior-posterior approach (Table 1). Preoperative cervical traction was not part of the surgical strategy for any of the surgeons in the panel for these cases. There was a broad range in the numbers of anterior (2–8) and posterior (4–22) fusion levels recommended. As a surgical treatment strategy, 43% of surgeons included a PSO (grade 6) or VCR (grade 7), and the remaining surgeons favored the use of multilevel facet releases (grade 1) and Ponte osteotomies (grade 2). The substantial variability in recommended approaches, posterior fusion levels,

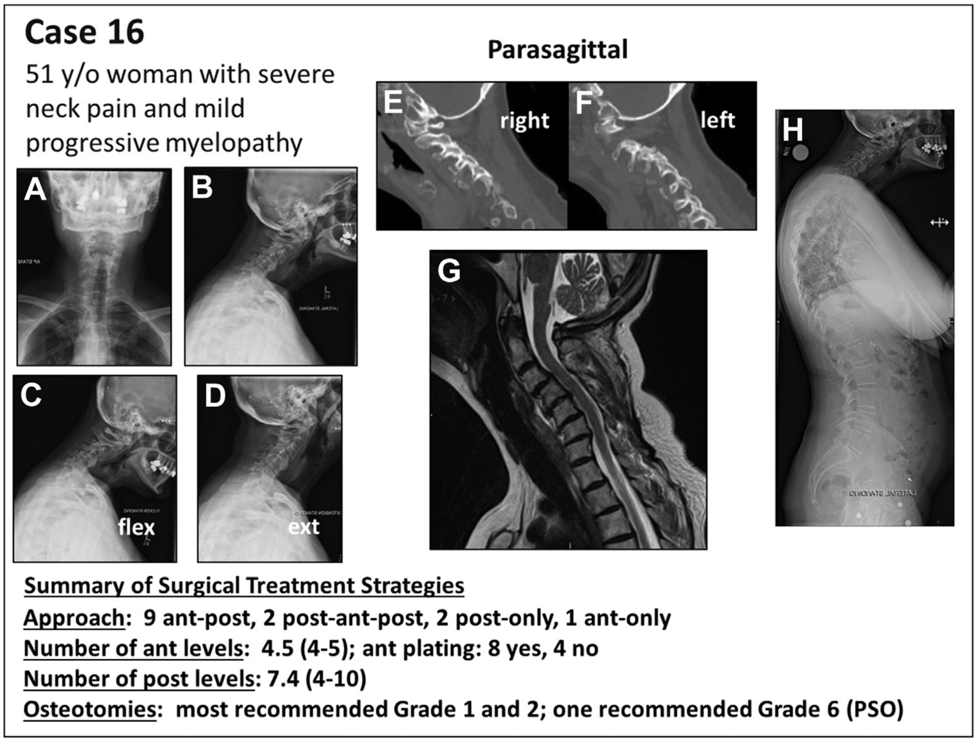

Figure 3. Representative case of a moderate midcervical apex kyphosis. The patient is a 51-year-old woman with severe neck pain and mild myelopathy. Shown are posteroanterior (**A**) and lateral (**B**) cervical radiographs, flexion (**C**) and extension (**D**) lateral cervical radiographs, right (**E**) and left (**F**) parasagittal cervical spine images from sagittal recontructions of computed tomographic imaging, midsagittal section of a T2-weighted magnetic resonance image of the cervical spine (**G**), and lateral full-length satanding spine radiograph (**H**). A summary of the surgical treatment strategies recommended by the panel is provided at the bottom of the figure. Ant, anterior; post, posterior; PSO, pedicle subtraction osteotomy; y/o, year-old.

and types of osteotomies for these cases are shown in an example case in Figure 6 (case 16).

Cases of cervical/cervical-thoracic scoliosis had the least agreement in approach (48% posterior only, 33% combined anterior-posterior, 17% anterior-posterior-anterior or posterior-anterior-posterior, 2% anterior only) and had marked variation in number of anterior (2—5) and posterior (6—19) fusion levels. There was also substantial variability in the recommended osteotomies for these cases, with 41% recommending a PSO (grade 6) or VCR (grade 7), whereas others favored use of multiple facet releases (grade 1) and Ponte osteotomies (grade 2) (Table 1). Preoperative cervical traction was recommended by a few of the surgeons (21%—36%) for these cases. The variability in surgical treatment strategy for cervical/cervical-thoracic scoliosis is shown in an example case in Figure 7 (case 10).

DISCUSSION

The present study shows marked variation in surgical treatment strategies for cervical deformity. Based on a series of 18 moderate to severe CSD cases that are representative of the general types of cervical and cervical-thoracic deformities, a panel of 14 experienced deformity surgeons provided recommendations for surgical approach(es), osteotomies, and fusion levels. Even for the least complex deformities (moderate midcervical apex kyphosis), there was a broad range of strategies, including use of preoperative traction, how to approach the spine (anteriorly, posteriorly, or both), the number of spinal fusion levels, and the types of soft tissue release and osteotomies. As the kyphosis apex moved caudally (cervical-thoracic junction/upper thoracic spine) and in cases with chin-on-chest kyphosis, there was greater agreement among surgeons with regard to surgical approach and application of osteotomies, with most surgeons favoring a posterior-only approach and a PSO (grade 6) or VCR (grade 7); however, the range in numbers of fusion levels remained markedly broad. Coronal deformities (cervical/cervical-thoracic scoliosis) had the least agreement in approach, had an exceptionally broad range in number of fusion levels, and 40% recommended aggressive 3-column osteotomies, whereas the remaining surgeons favored multilevel low-grade osteotomies. Collectively, these findings highlight a considerable lack of agreement on surgical treatment strategies for CSD and strongly suggest that further study is warranted to better understand these differences in treatment strategies and whether a more standardized approach may prove valuable for surgical planning, improving safety of care, optimizing patient outcomes, and reducing cost.

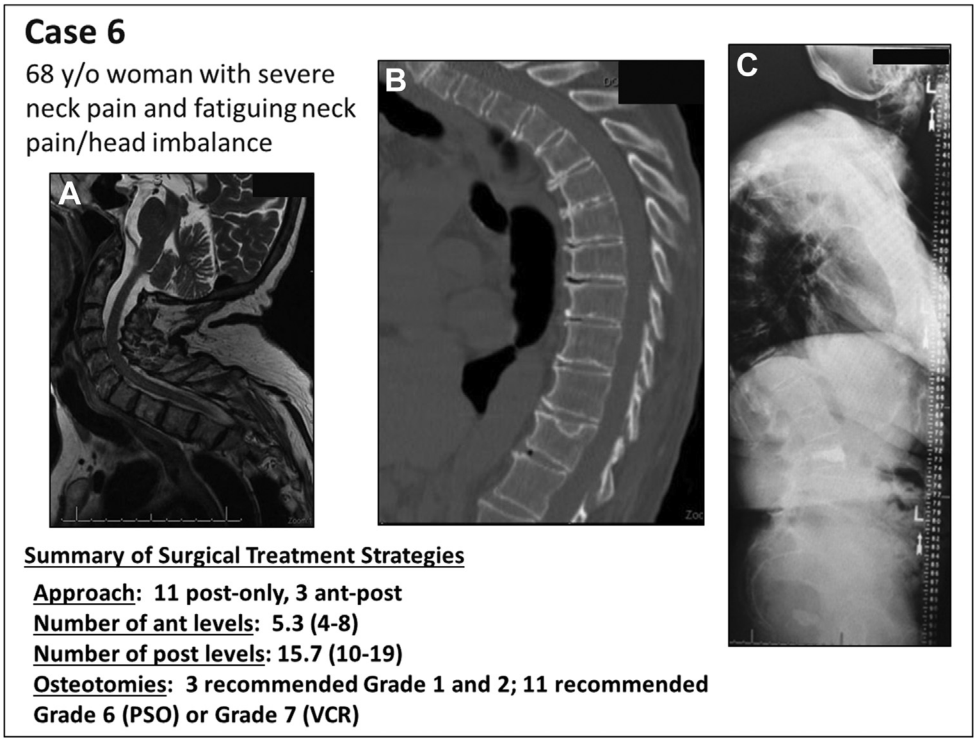

Figure 4. Representative case of a cervical kyphosis with apex at the cervical-thoracic junction or upper thoracic spine. The patient is a 68-year-old woman with severe neck pain and fatiguing neck pain/head imbalance. Shown are midsagittal section of a T2-weighted magnetic resonance image of the cervical spine (**A**), midcervical-thoracic spine image from sagittal recontructions of computed tomographic imaging (**B**), and lateral full-length satanding spine radiograph (**C**). A summary of the surgical treatment strategies recommended by the panel is provided at the bottom of the figure. Ant, anterior; post, posterior; PSO, pedicle subtraction osteotomy; VCR, vertebral column resection; y/o, year-old.

There are likely multiple reasons for the variation in treatment strategies for CSD observed in the present study. One of the primary reasons for these differences may be the lack of an established, validated, and widely accepted classification system for CSD. Such a classification system can not only provide basic grouping of various deformity patterns but can also be clinically useful by serving as a guide for patient management and a basis for evidence-based care. These benefits have been shown for adult thoracolumbar spinal deformity through development and application of the Scoliosis Research Society (SRS)-Schwab classification, which provides direct classification of patients based on parameters with the strongest correlations with standardized health-related quality of life measures.[34-37] The Ames-Smith classification has recently been proposed as a novel cervical deformity classification that includes a deformity descriptor and 5 modifiers that incorporate sagittal regional and global spinopelvic alignment and neurologic status.[7] The descriptors include C, CT, and T, which correspond to primary cervical kyphotic deformities with an apex in the cervical, cervical-thoracic, or thoracic spine, respectively; S for primary coronal deformity with a coronal Cobb angle of at least 15 degrees; and CVJ for primary cranial vertebral junction deformities. The modifiers include C2–C7 sagittal vertical axis, horizontal gaze (chin-brow to vertical angle), T1 slope minus C2–C7 lordosis, myelopathy (modified Japanese Orthopedic Association score), and the SRS-Schwab classification for thoracolumbar deformity. Similar to the benefits for surgical planning for adult thoracolumbar deformity conveyed by the SRS-Schwab classification, application of the Ames-Smith classification for cervical deformity may improve surgical planning and outcomes for CSD by focusing attention on factors that affect outcome. This may also result in a more standardized approach to surgical management. However, considerable work remains to be done with regard to assessing whether specific treatment algorithms can provide clinical advantage and whether such a classification system has the ability to meaningfully differentiate between appropriate treatments.

Variation in treatment planning for CSD may also be introduced by a lack of appreciation of the location of the primary deformity. A recent study from Ames and colleagues[38] reported a significant chain of correlation in sagittal spinopelvic alignment that is based on pelvic morphology (pelvic incidence) and extends sequentially through the lumbar, thoracic, and cervical spine. Thus, pathologic changes in 1 region of the spine may affect the alignment in other regions.[1,2,23,27,38-41] For example, a patient may show a significant

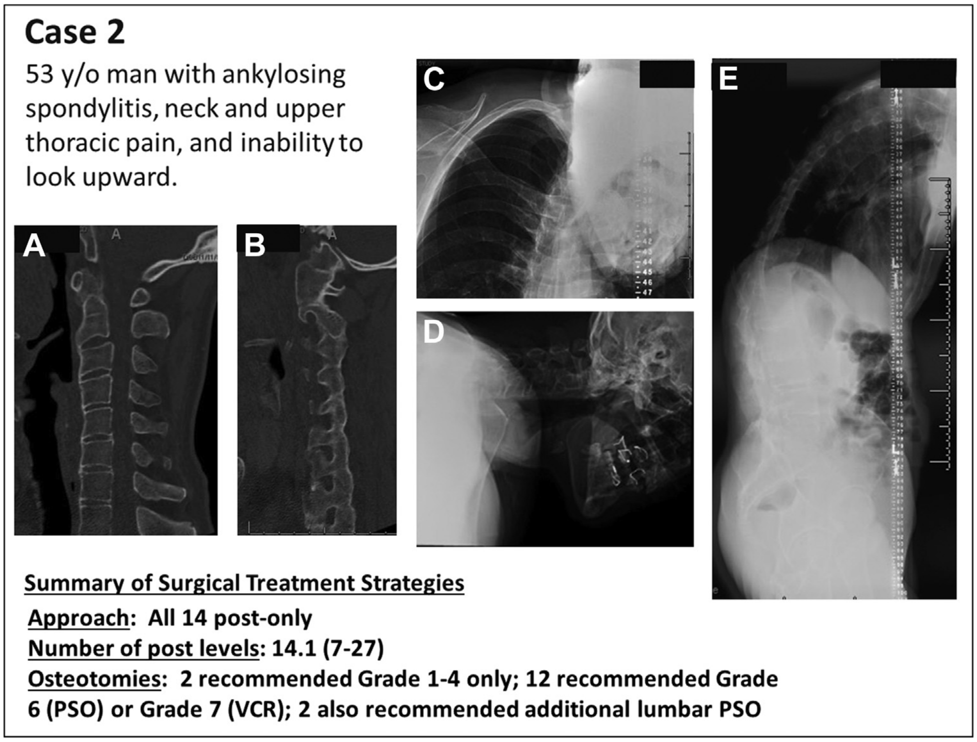

Figure 5. Representative case of a chin-on-chest kyphosis. The patient is a 53-year-old man with ankylosing spondylitis, neck and upper thoracic pain, and inability to look upward. Shown are midline (**A**) and parasagittal (**B**) cervical spine images from sagittal recontructions of computed tomographic imaging, posteroanterior (**C**) and lateral (**D**) cervical radiographs, and lateral full-length satanding spine radiograph (**E**). A summary of the surgical treatment strategies recommended by the panel is provided at the bottom of the figure. Post, posterior; PSO, pedicle subtraction osteotomy; VCR, vertebral column resection; y/o, year-old.

cervical kyphosis, but the apex of this deformity may be in the upper or midthoracic spine. A patient may also show a cervical deformity that is compensatory for a thoracolumbar deformity.[23,40] This underscores the potential value of assessing global spinopelvic alignment with full-length standing spine radiography when evaluating what may appear to be an isolated cervical deformity[42] and shows the rationale for including the SRS-Schwab adult thoracolumbar deformity classification as a modifier in the Ames-Smith cervical deformity classification. Although standing long-cassette radiographs can provide valuable information, we do not necessarily suggest that they should be obtained for every patient with cervical disease. Patient history and physical examination are important to help guide the appropriate selection of imaging studies. Physical examination may not show some substantial deformities; for example, if the patient is compensating for sagittal malalignment with a high degree of pelvic retroversion. In addition, the apex and extent of a deformity may not be readily apparent based on focused cervical imaging but instead be better defined with long-cassette standing radiographs. The physician must weigh the risks and benefits in deciding which imaging studies to obtain.

Another reason for the marked variation in surgical planning shown in the present study may be differences in training background and experience with different techniques. For example, although the first descriptions of 3-column osteotomies of the cervical spine and cervical-thoracic junction were reported more than 50 years ago,[6] it has only been more recently that the technique and supporting instrumentation have advanced to enable broader and safer application of these osteotomies.[8,9,11,24,25] For surgeons adept at performing a PSO in the cervical spine or at the cervical-thoracic junction, a significant fixed kyphotic deformity may be corrected with a single-stage posterior approach. Other surgeons may favor multiple approaches (eg, anterior-posterior or posterior-anterior-posterior) and use of a combination of lower-grade osteotomies. This variation can be readily seen in the present series in patients with cervical kyphosis with apex at the cervical-thoracic junction or upper thoracic spine, patients with chin-on-chest deformities, and in patients with midthoracic kyphosis that was greater than the degree of cervical kyphosis. In contrast to fixed sagittal deformities in the thoracolumbar spine, gaining such an experience with PSO in the cervical spine in practice may be more challenging because of the substantially lower number of patients

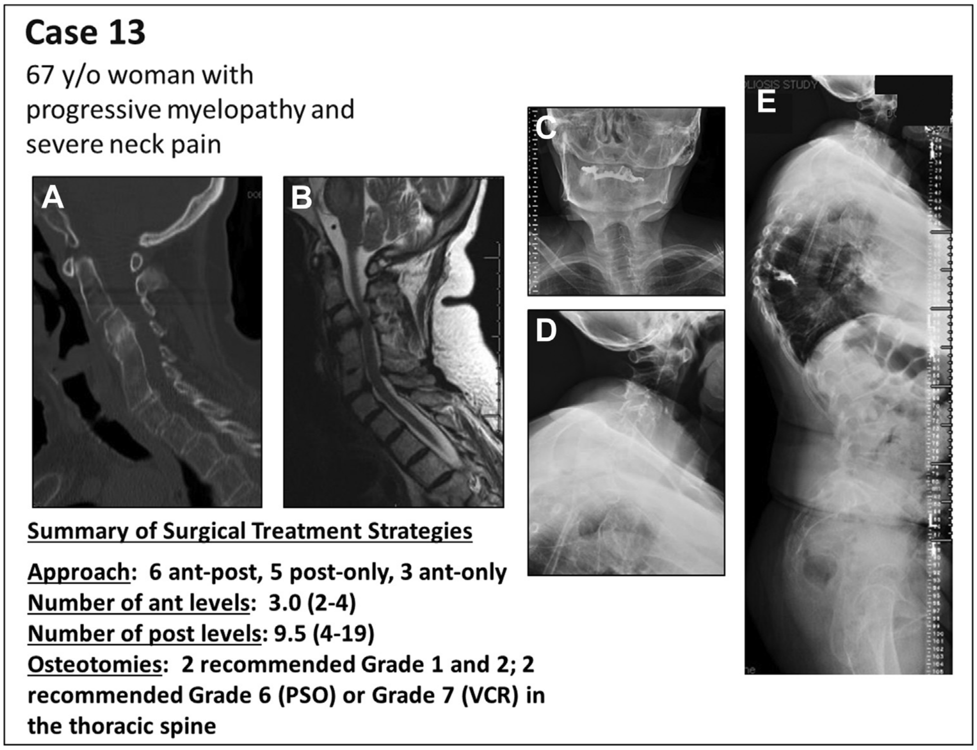

Figure 6. Representative case of mild cervical kyphosis associated with greater thoracic kyphosis. The patient is a 67-year-old woman with progressive myelopathy and severe neck pain. Shown are midline cervical spine images from sagittal recontructions of computed tomographic imaging (**A**), midsagittal section of a T2-weighted magnetic resonance image of the cervical spine (**B**), posteroanterior (**C**) and lateral (**D**) cervical radiographs, and lateral full-length satanding spine radiograph (**E**). A summary of the surgical treatment strategies recommended by the panel is provided at the bottom of the figure. Ant, anterior; post, posterior; PSO, pedicle subtraction osteotomy; VCR, vertebral column resection; y/o, year-old.

with CSD compared with thoracolumbar deformity patients and because of the greater risks of neurologic and vascular complications in the cervical spine.

The primary limitation of the present study is the inability of the surgeon providing management recommendations to physically examine the corresponding patient. Direct assessment of functional and range of motion limitations, for example, can be helpful in treatment planning. Complex cervical deformity cases often require more extensive workup with regard to both history and advanced imaging to optimize decision making. In addition, the panel of surgeons was predominantly composed of orthopedic surgeons (71%), with a lesser representation of neurosurgeons, which did not allow for assessment of variation in treatment plans based on training background. Given the wide variety of cervical deformities to represent in the survey and the numbers of cases that could be selected for each type, large numbers of cases could not be included for any specific subtype of deformity, which limited the ability to provide detailed analysis by deformity subtype. Although efforts were made to include a broad range of typical cervical deformity types, there are less common types that were not represented.

CONCLUSIONS

Among a panel of deformity surgeons, there was marked lack of consensus on recommended surgical approach, osteotomies, and fusion levels for CSD. These variations may have significant impact on complication risk, patient outcomes, and cost. In the present study, the greatest agreement was observed for cases with a kyphosis apex at the cervical-thoracic junction or upper thoracic spine and in cases with chin-on-chest kyphosis. For these cases, most surgeons recommended a posterior-only approach with a PSO or VCR but had marked variation in the range of recommended fusion levels. The least agreement was seen for cases of cervical or cervical-thoracic scoliosis, for which approaches ranged from anterior and posterior only to posterior-anterior-posterior and recommended osteotomies were almost evenly split between low and high grade. We view these findings as a first step toward defining the magnitude of variation in the surgical treatment of patients with CSD. Further understanding these differences and assessing their potential impact may prove valuable for surgical planning, improving the safety of care, optimizing patient outcomes, and reducing cost.

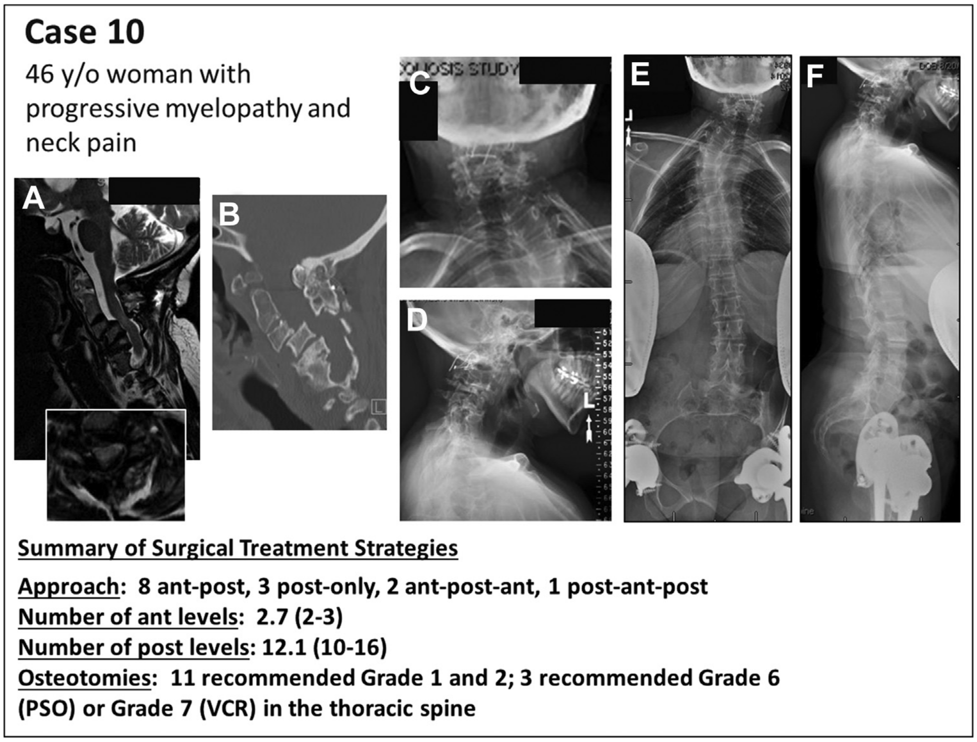

Figure 7. Representative case of cervical/cervicothoracic scoliosis. The patient is a 46-year-old woman with progressive myelopathy and neck pain. Shown are midsagittal section of a T2-weighted magnetic resonance image of the cervical spine with inset showing axial T2-weighted setion at the level of C3-C4 (**A**), midline cervical spine images from sagittal recontructions of computed tomographic imaging (**B**), posteroanterior (**C**) and lateral (**D**) cervical radiographs, and posteroanterior (**E**) and lateral (**F**) full-length satanding spine radiographs. Ant, anterior; post, posterior; PSO, pedicle subtraction osteotomy; VCR, vertebral column resection; y/o, year-old.

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