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Defining Cervical Sagittal Plane Deformity – When Are Sagittal Realignment Procedures Necessary in Patients Presenting Primarily With Radiculopathy or Myelopathy?

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Objective: It remains unclear whether cervical sagittal deformity (CSD) should be defined by radiographic parameters alone versus both clinical and radiographic factors, and whether radiographic malalignment by itself warrants a CSD corrective surgery in patients who present primarily with neurologic symptoms.
Methods: We administered a survey to a group of expert surgeons to evaluate whether radiographic parameters alone were sufficient to diagnose CSD, and in which scenarios surgeons recommend a CSD realignment procedure versus addressing the neurologic symptoms alone.
Results: No single radiographic criteria reached a 50% threshold as being sufficient to establish the diagnosis of CSD. When asymptomatic radiographic malalignment was present, a sagittal deformity correction was more likely to be recommended in patients with myelopathy versus those with radiculopathy alone. The majority of surgeons recommended deformity correction when symptoms of cervical deformity were present in addition to radiographic malalignment (85% with deformity symptoms and radiculopathy, 93% with deformity symptoms and myelopathy).
Conclusion: There is no consensus on which radiographic and/or clinical criteria are necessary to define the presence of CSD. We recommend that symptoms of cervical deformity, in addition to radiographic parameters, be considered when deciding whether to perform deformity correction in patients who present primarily with myelopathy or radiculopathy.

Keywords: Kyphosis, Spinal cord compression, Cervical spine deformity, Radiculopathy, Myelopathy, Deformity correction

INTRODUCTION

Cervical sagittal deformity (CSD) is an extremely disabling condition that can have a myriad of etiologies including congenital, degenerative disease, posttraumatic, iatrogenic, and inflammatory, among others.[1] CSD can cause symptoms from the deformity itself, such as difficulty holding one's head upright with an inability to maintain horizontal gaze, neck pain, and difficulty swallowing in severe cases. In addition to the symptoms related to the spinal malalignment, CSD can often also be associated with symptoms of radiculopathy and/or myelopathy from cervical nerve root or spinal cord compression. Indeed, CSD itself may be a cause of cervical myelopathy in certain situations from draping of the spinal cord over anterior pathology

causing an increase in longitudinal spinal cord tension.[2,3]

While there are several radiographic parameters commonly cited in the literature as inclusion criteria for entry into studies on CSD,[4] the question remains as to whether these parameters are sufficient to warrant a diagnosis of CSD in clinical practice. Many patients present with radiculopathy or myelopathy in the setting of sagittal alignment that is not "perfect," but do not have a severe chin-on-chest deformity that obviously requires concomitant correction. Indeed, there have been many publications examining the postoperative outcomes of cervical deformity patients utilizing a large multicenter database with the following inclusion criteria: cervical kyphosis C2-C7 Cobb angle >10°; cervical scoliosis C2–7 coronal Cobb angle >10°, C2–7 sagittal vertical axis (cSVA) >4 cm, or chin-brow vertical angle >25°.[5-8] Despite these radiographic definitions, it remains unclear whether patients who meet those radiographic criteria of cervical deformity actually require concomitant cervical deformity correction when they present primarily with symptoms of myelopathy and/or radiculopathy.

To begin to answer this question, we surveyed an international group of experienced cervical deformity surgeons on several clinical scenarios to determine if there is consensus as to (1) the definition of a cervical sagittal plane deformity in clinical practice, and (2) when a myelopathy/radiculopathy patient with radiologic malalignment merits additional CSD correction with its associated risks, versus when a smaller procedure to only treat the myelopathy and/or radiculopathy is sufficient.

MATERIALS AND METHODS

A survey (Supplementary Material) was distributed through REDCap (Project REDCap, Vanderbilt University) to 82 expert cervical spine surgeons (current and past Board Members from the Cervical Spine Research Society [CSRS], CSRS Asia Pacific, and CSRS Europe, as well as those who have published extensively in CSD) with differing experience, training background (neurosurgery vs. orthopaedic surgery), and practice environment (university setting vs. private or hospital employed). The questions, developed by the authors of this study, were designed to determine whether the current published radiographic criteria were sufficient alone to establish a diagnosis of CSD or whether other clinical and physical exam factors were also thought to be necessary in the diagnosis of CSD. We also presented several clinical vignettes to determine which radiographic parameters would require correction in the setting of clinical signs and symptoms such as radiculopathy, myelopathy, axial neck pain, and difficulty holding one's head upright.

Statistical analyses were performed using the R ver. 4.1.3 (R Foundation for Statistical Computing, Vienna, Austria). Chi-square analyses in Tables 1 and 2 were used to assess whether participants showed a preference for one option over another (i.e., significantly differed from an equal split across options).

RESULTS

We received survey responses from 41 surgeons (33 orthopaedic surgeons, 8 neurosurgeons) with 93% working in an academic environment. 35 surgeons (85%) were from North America, 2 (5%) were from Europe, and 4 (10%) were from Asia. Forty-one percent of surgeons had 6–15 years of experience and 59% had 16+ years of experience (mean, 19.7±9.0 years). Eighty percent of the surgeons devote greater than 50% of their surgi-

Table 1. In a patient with myelopathy and with the clinical signs and symptoms listed below, would you offer the patient a "more extensive" operation than what is needed to adequately treat the myelopathy in order to normalize the sagittal plane radiographic abnormalities (C2–7 SVA >4 cm, C2–7 kyphosis >10°, CBVA >25°)?

Variable	Yes	No	p-value
Myelopathy alone	21 (51)	20 (49)	0.88
Myelopathy with neck pain	22 (54)	19 (46)	0.64
Myelopathy with neck pain and difficulty holding head upright	38 (93)	3 (7)	<0.001

Values are presented as number (%).
SVA, sagittal vertical axis; CBVA, chin-brow vertical angle.
The p-values are for goodness of fit chi-square tests using 50% proportions (i.e., no preference) as expected values.

Table 2. In a patient with radiculopathy and with the clinical signs and symptoms listed below, would you offer the patient a "more extensive" operation than what is needed to adequately treat the radiculopathy in order to normalize the sagittal plane radiographic abnormalities (C2–7 SVA >4 cm, C2–7 kyphosis >10°, CBVA >25°)?

Variable	Yes	No	p-value
Radiculopathy alone	4 (10)	37 (90)	<0.001
Radiculopathy with neck pain	7 (17)	34 (83)	<0.001
Radiculopathy with neck pain and difficulty holding head upright	35 (85)	6 (15)	<0.001

Values are presented as number (%).
SVA, sagittal vertical axis; CBVA, chin-brow vertical angle.
The p-values are for goodness of fit chi-square tests using 50% proportions (i.e., no preference) as expected values.

Table 3. Is the radiographic criteria or clinical symptom listed below, by themselves, sufficient to establish a diagnosis of cervical sagittal deformity?

Variable	Yes	No
C2–7 SVA, >4 cm	16 (39)	25 (61)
C2–7 kyphosis >10°	13 (32)	28 (68)
CBVA >25°	20 (49)	21 (51)
Difficulty holding head upright	10 (24)	31 (76)

Values are presented as number (%).
SVA, sagittal vertical axis; CBVA, chin-brow vertical angle.

cal practice to treating patients with cervical spine disorders. Ninety-three percent of the surgeons perform a realignment procedure for CSD at least once every 3 months.

1. Definition of Cervical Sagittal Plane Deformity in Clinical Practice

The survey results demonstrate that CSD remains difficult to define, as no single radiographic criteria (each of which alone has commonly been used as an inclusion criterion for entry into studies on cervical deformity surgery) reached even a 50% threshold as being sufficient to establish a diagnosis of CSD in clinical practice (Table 3). Even when all 3 of these radiographic criteria were combined with patient-reported symptoms of difficulty holding one's head upright, 68% of surgeons still felt this combination was insufficient to establish the diagnosis of CSD.

2. When Does a Patient Presenting Primarily With Myelopathy and/or Radiculopathy in the Setting of Radiographic Malalignment Merit Additional CSD Correction With Its Associated Risks?

An extensive sagittal deformity correction procedure beyond that needed to just treat the neurologic disorder was much more likely to be recommended in patients with myelopathy and asymptomatic radiographic malalignment (51%; Table 1) versus those with radiculopathy and asymptomatic radiographic malalignment (10%; Table 2). However, despite that, only 51% recommended extensive deformity correction even in those with myelopathy and asymptomatic radiologic malalignment. The presence of neck pain did not substantially change the recommendation for either radiculopathy (17%) or myelopathy (54%) patients.

When examining proportions, surgeons were more likely to recommend extensive deformity correction in both radiculopathy and myelopathy patients when they had concomitant symptoms of deformity (i.e., neck pain associated with difficulty holding one's head upright) along with radiologic malalignment (radiculopathy 85%, myelopathy 93%).

DISCUSSION

Our study shows that there is poor consensus amongst a group of worldwide cervical spine surgery experts on the definition of CSD. Similarly, the indications for a sagittal plane corrective procedure versus a procedure designed to simply address the myelopathy and/or radiculopathy remains a topic of debate. Although, degenerative cervical disorders causing myelopathy and radiculopathy are common, symptomatic CSD requiring corrective surgery is relatively more rare, especially when compared to thoracolumbar spinal deformity.[1,9] The question of when cervical sagittal realignment procedures are needed is important because CSD procedures are typically more extensive than procedures for degenerative cervical pathology, require fusion of a greater number of motion segments, more often involve combined anterior and posterior approaches, more commonly require osteotomies, and have a higher rate of complications.[10-15] On the other hand, while operations to simply treat radiculopathy and/or myelopathy are often less invasive than CSD procedures, they may potentially have the risk of undertreating the problem and not addressing all potential pain generators or dynamic neurologic compression. In this study, we found that no single radiographic or clinical criteria by itself was sufficient to establish a diagnosis of CSD. In those with asymptomatic radiographic malalignment, we found that expert surgeons are much more likely to recommend a sagittal realignment procedure when patients have myelopathy compared to radiculopathy. However, even in that setting, deformity correction was recommended by only 51% of surgeons. Finally, surgeons were much more likely to recommend deformity correction surgery in patients with concomitant symptoms of sagittal plane deformity (93% for those with myelopathy, 85% for those with radiculopathy). These results suggest that clinical symptoms of deformity should be strongly considered in clinical decision-making, rather than relying solely on radiographic alignment criteria alone.

Our understanding of CSD is still evolving as we gain more insight into normative cervical and thoracolumbar alignment.[16-19] While it is well known that degenerative cervical conditions have significant negative effects on health-related quality of life (HRQoL), it remains unclear as to what extent CSD itself negatively affects HRQoL. As there are no current widely-adopted specific CSD HRQoL instruments, we do not have a full understanding

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of the impact of CSD that is independent of the negative effects that myelopathy and radiculopathy have on HRQoL. Further, it has been shown that approximately one-third of the asymptomatic population has a kyphotic alignment of the cervical spine.[20,21] Given this, it is somewhat surprising that we found only 32% of expert surgeons felt that C2–7 kyphosis >10° was sufficient to establish a diagnosis of CSD. Although cervical kyphosis is frequently present in asymptomatic individuals, sagittal malalignment is very poorly tolerated in the thoracolumbar spine and lumbar kyphosis is less commonly present in normal, asymptomatic patients.[22] It is known, however, that kyphotic cervical alignment in the presence of anterior compressive disease increases longitudinal cord tension and there may be less dorsal migration of the cord with posterior decompression.[23,24] Even with this in mind, not all patients need to achieve the same amount of lordosis after a cervical spine fusion procedure. Passias et al. reported on the relationship between myelopathy, surgical deformity correction, and patient-reported outcomes (PROs) and found no relationship between PRO improvement and cervical-specific sagittal alignment measures.[25] Other studies have suggested an association between postoperative cervical lordosis minus T1 slope and worsened disability after cervical deformity correction.[26] Given these somewhat disparate results, it is safe to say that we do not yet fully understand which patients require lordotic alignment after cervical reconstruction. Rather than the amount of overall cervical lordosis, the final C2 tilt or C4 tilt may ultimately prove to be more important with regards to restoring normal alignment, but this will need further prospective validation.[20,27] In this study, we sought to specifically focus on cervical radiographic parameters that have been widely published in literature to date, but certainly understand the value in discussing additional parameters as more evidence is obtained over time.

In addition to cervical lordosis, C2–7 SVA <4 cm has been reported as an important measure of sagittal alignment. However, it is not clear what the target C2–7 SVA should be for all patients undergoing cervical spine surgery. Normal C2–7 SVA has been reported to be 16.8±11.2 mm.[28] Previous studies have reported that C2–7 SVA >4 cm is associated with worsened PROs after multilevel posterior cervical deformity surgery,[29] and this criterion is part of the comprehensive cervical spine deformity classification system which was proposed by Ames et al.[19] Although these studies certainly suggest that a C2–7 SVA of <4 cm may be beneficial to achieve in those undergoing cervical deformity correction, they should not necessarily be interpreted as meaning that all patients with radiculopathy or myelopathy need to have a value <4 cm to achieve an optimal outcome. By contrast, in a recent study by Karamian et al.[30] of patients undergoing 1–3 level anterior cervical discectomy and fusion, those with a preoperative C2–7 SVA of >4 cm actually had greater improvement in Neck Disability Index scores postoperatively versus those with a C2–7 SVA <4 cm, even though the SVA values remained >4 cm in the former group and <4 cm in the latter. In other words, in patients with primarily radiculopathy or myelopathy, C2–7 SVA may not necessarily be a major driver of outcomes. Further, given that C2–7 SVA is dynamic and is affected not only by the intrinsic cervical alignment but also by other postural factors (thoracolumbar spinal alignment, lower extremity compensation, etc.), it should not be solely relied upon when planning a cervical sagittal corrective procedure. Accordingly, we found that only 39% of experts felt that C2–7 SVA was sufficient to establish a diagnosis of CSD, although 93% of surgeons felt it important to normalize C2–7 SVA along with the other radiographic parameters when cervical deformity correction is performed. More work will be needed to understand which radiographic measures are most important to normalize to maximize postoperative PROs and return to activities with cervical deformity correction.

Given the high morbidity of cervical deformity surgery, it is certainly important to carefully select patients who truly require aggressive sagittal correction versus those who will benefit from a procedure to simply address the myelopathy and radiculopathy. Here we found that 90% of surgeons in cases of radiculopathy, and 49% of surgeons in cases of myelopathy would not perform an aggressive sagittal realignment procedure beyond what is necessary to treat the neurological issue to correct an asymptomatic radiographic abnormality. If patients have truly symptomatic deformity with symptoms of neck pain associated with difficulty holding one's head upright and with horizontal gaze, along with a clear radiographic deformity, then a sagittal realignment procedure is indicated (Fig. 1E–F). However, if patients simply have radiographic abnormalities (e.g., cervical kyphosis, C2–7 SVA >4 cm, etc.) without a clinically visible or symptomatic deformity (Fig. 1A–D), then in our opinion, and based on these results, a more limited procedure to treat the myelopathy/radiculopathy may be recommended.

There are several limitations associated with this study. The percentage of total respondents was only 50% of those invited. However, this is consistent with previous response rates for other published spine surveys.[31-34] Also, only 20% of the respondents had a neurosurgical training background, and only 15% were from outside North America. Additionally, former/current CSRS

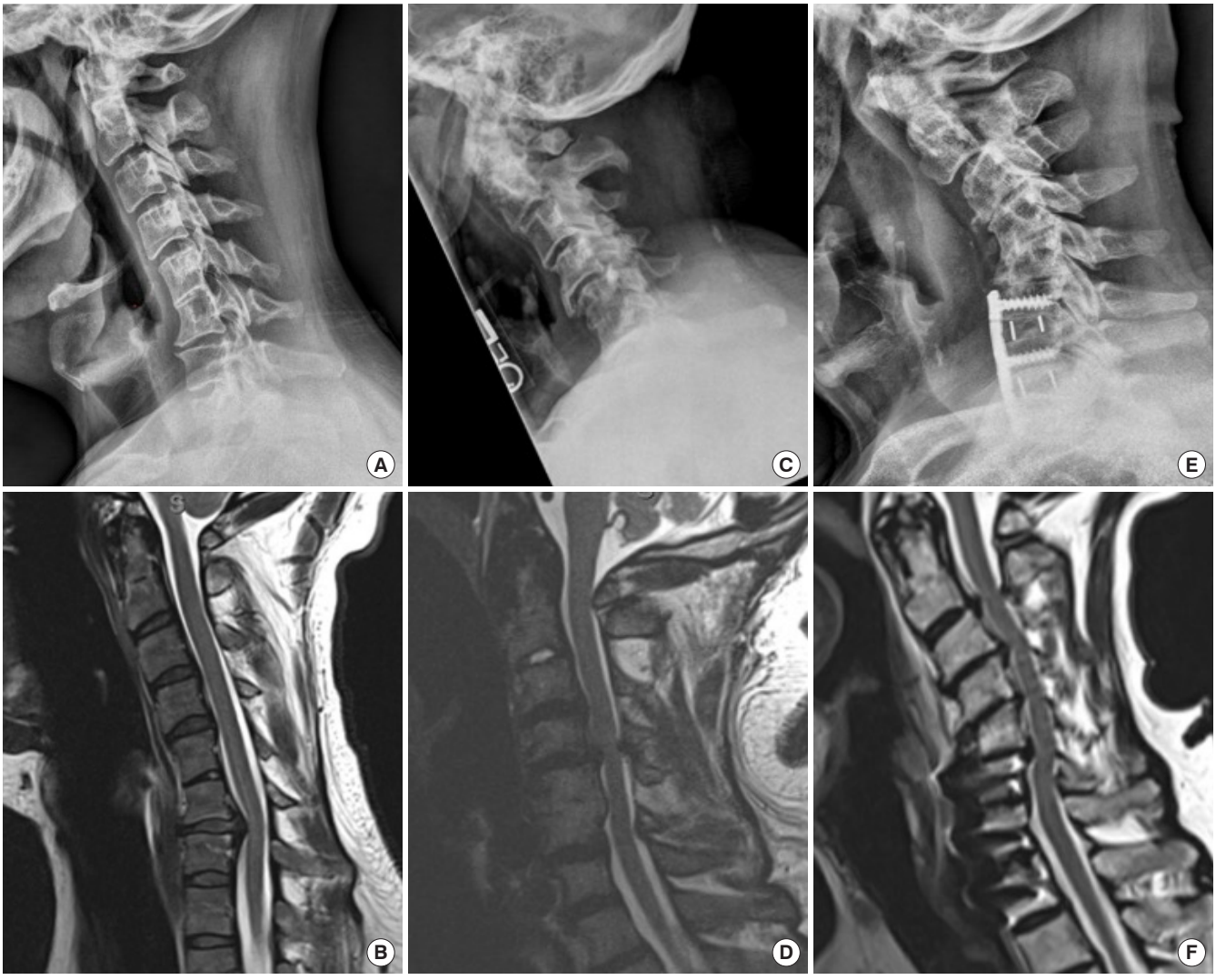

Fig. 1. Representative patients all with symptoms of radiculopathy and/or myelopathy with radiographic malalignment. (A, B) Patient with cervical radiculopathy with no neck pain, C2–7 SVA >4 cm, and C2–7 kyphosis >10°. (C, D) Patient with cervical myelopathy with chronic axial neck pain, C2–7 SVA >4 cm, C2–7 kyphosis >10°, but no visual appearance of deformity and no difficulty with horizontal gaze or holding one's head upright. (E, F) Patient with cervical myelopathy with axial neck pain, difficulty holding his head upright, unable to maintain horizontal gaze, C2–7 SVA >4 cm, C2–7 kyphosis >10°.

leadership and those who have published extensively in CSD-related topics may not be representative of all cervical spine surgeons. These factors could have led to bias in the results. Despite this, much of the current literature and education related to CSD were developed and provided by those invited for this survey. Lastly, the case descriptions we provided were standardized based on symptom descriptions, and did not include the actual images nor clinical photos for evaluation. We selected this approach in order to increase the generalizability of findings, rather than focusing on the specifics associated with a particular case. Nevertheless, we do recognize that looking at images may certainly impact the decision-making process. Despite these limitations, this is the first survey that seeks to understand when a smaller procedure to treat only the radiculopathy and myelopathy may be sufficient without specifically attempting to correct the radiographic malalignment, and when a more extensive sagittal realignment procedure may be warranted.

CONCLUSION

Despite numerous published studies defining CSD by radiographic criteria alone, there is no consensus amongst a diverse group of expert cervical spine surgeons as to what radiographic criteria are necessary to define the presence of cervical defor-

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mity in clinical practice. Expert surgeons are more likely to perform CSD realignment procedures in patients with myelopathy versus those with radiculopathy alone, and were also more likely to recommend an extensive deformity correction when clinical symptoms of deformity were present along with the radiologic malalignment. Therefore, based on expert opinion, surgeons should not necessarily recommend extensive CSD realignment operations in all patients with radiologic malalignment alone, but may carefully consider doing so when symptoms of deformity are also present.

Limitations of our report include those inherent to survey studies and the limited numbers of spine surgeons from nonacademic medical centers responding to the survey. However, given the responses from both neurosurgeons and orthopaedic spine surgeons and from both very senior and midcareer surgeons, we believe this provides an accurate representation of expert practice patterns regarding the treatment of CSD. More work is necessary to refine the definition of CSD and what patients will ultimately benefit from a sagittal plane realignment procedure.

NOTES

Supplementary Material: Supplementary Survey Questions can be found via https://doi.org/10.14245/ ns.2244924.462.

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