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# Spinal alignment, surgery, and outcomes in cervical deformity: A practical guide to aid the spine surgeon

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ABSTRACT

Compared to the thoracolumbar spine, the literature on cervical spine alignment is scarce. While a consistent number of articles have been published, few analyze the ideal surgical approaches for each type of deformity and the optimal amount of correction to achieve. This paper provides a comprehensive review of current literature on cervical spinal deformities (with or without myelopathy) and their surgical management; it is our goal to create a framework on which surgical planning can be made. A general assessment of the actually utilized parameters and correlation between the cervical and thoracolumbar spine alignment is presented. Moreover, we provide an analysis of cervical surgical approaches (anterior, posterior, or combined), techniques (laminoplasty, laminectomy and fusion, anterior cervical discectomy and fusion, corpectomy), and their indications. Finally, a complete evaluation of outcomes and postoperative health-related quality of life (HRQOL) measures based on questionnaires (NDI, VAS, SF-36, mJOA) is discussed. Several prospective studies would be useful in understanding how cervical alignment may be important in the assessment and treatment of cervical deformities with or without myelopathy. In particular, future works should concentrate on the correlation between cervical alignment parameters, disability scores, and myelopathy outcomes. We propose, via comprehensive literature review, a guide of practical key points on surgical techniques, cervical alignment, and symptom improvement goals surgeons should aim to achieve for each patient.

## 1. Introduction

The cervical spine is a complex system of joints that allows the widest range of motion relative to the rest of the spine and also supports the mass of the head. A variety of disorders and complications can occur, many of which lead to misalignment pathology. Abnormalities of the cervical spine are usually quite debilitating and adversely affect the overall function and health-related quality of life (HRQOL) of the patient [1]. Furthermore, the cervical spine plays a pivotal role in influencing global subjacent spinal alignment and pelvic tilt as compensatory changes occur to maintain horizontal gaze. Over the last decade, multiple publications have identified the importance of radiographic parameters in the thoracolumbar spine that have direct effects on surgical outcomes and quality of life [2]. Further studies have determined the critical thresholds and global and regional parameters for sagittal surgical realignment [2].

However, relatively few publications have defined these normative values for cervical alignment, and even fewer have directly evaluated the influence of segmental, regional, and global balance on outcomes in cervical spine surgery. With improved understanding of cervical deformity and the availability of advanced surgical instrumentation and neuro-monitoring techniques, an increasing number of complex cervical spine procedures are being performed [3,4]. Understanding reciprocal compensatory mechanisms involved with such deformities not only allows a comprehensive description of the deformity but may also help in avoiding unnecessary fusions to achieve optimal surgical outcomes [5,6].

Currently, indications for surgery to correct cervical alignment are

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not well-defined, and there are no set standards regarding the amount of surgical correction to be achieved. Moreover, classifications of cervical deformity have yet to be fully established and their treatment options defined and clarified.

The purpose of this article is to provide a comprehensive narrative review of cervical alignment parameters, normal versus pathological cervical alignment values, and an understanding of how alignment is associated with cervical deformity and myelopathy. Building upon this knowledge, we describe applicable surgical strategies and management, outcomes with the discussion of HRQOL measures in patients with cervical deformity, and postoperative complications. Finally, we provide a basic set of pre- and post-operative guidelines to inform surgical management and ensure the best results.

## 2. Cervical parameters

The cervical spine is primarily responsible for supporting the head over the body. In the sagittal plane, the center of mass of the head directly overlies the occipital condyle, approximately 1 cm above and anterior to the external auditory canal [2]. Any deviations from the normal alignment of the mass of the head result in an increase in anterior or posterior (cantilever) loads, which subsequently induce an increase in cervical muscular energy expenditure [2].

The natural curvature of the cervical spine maintains a lordotic shape as a result of the wedge-shaped cervical vertebrae and the need to compensate (in order to maintain a straight alignment of the head) for the kyphotic curvature of the thoracic spine [7–9]. A loss of normal cervical lordosis or the development of cervical kyphosis is associated with neck pain and disability [9–12].

A complete set of standing cervical spine x-rays including the lower portion of the head and up to T1 (if visualization permits) is essential to evaluate the cervical alignment parameters [1]. In situations where visualization is poor and advanced computed tomographic imaging is not available, open mouth films to evaluate the odontoid and swimmer's lateral view films to evaluate the cervicothoracic junction may be required, though these are more frequently used in a traumatic setting. In order to evaluate the overall global alignment of the spine, standing posteroanterior (PA) or anteroposterior (AP) plus lateral 36- inch cassette x-rays that include the femoral heads are required to measure the cervical plumb line (sagittal and coronal planes) [2,13]. It is important to remember that the cervical spine is not isolated and that deformity may be happening in the thoracic or lumbar spine with compensatory mechanisms in the cervical spine [14].

Flexion/extension imaging is also helpful in evaluating these patients. Listhesis with movement can signify instability at the levels of interest, and furthermore, these tests can differentiate flexible from rigid deformities. CT imaging is helpful in understanding potential treatment algorithms. Though performed with the patient in the supine position, a more accurate evaluation of bone health (i.e., osteoporosis or osteopenia) and anatomy (lateral mass sizes, fused joints, osteophytic growths, calcified discs) relative to X-rays can be made which guide surgical approach options.

The three methods to assess cervical lordosis (CL) include Cobb angles, the Harrison posterior tangent method, and Jackson physiological stress lines [14]. The Cobb angle method measures the lordosis from either C1–C7 or C2–C7 and involves drawing 4 lines: a straight line from the inferior endplate of C2, a perpendicular line that intersects at 90 degrees with this line, then a straight line from the inferior endplate of C7 and a perpendicular line that intersects at 90 degrees with this line. The Cobb angle is determined by the angle resulting from the two perpendicular lines from the endplates at C2 and C7 (Fig. 1A). The Harrison posterior tangent method involves drawing parallel lines to the posterior surfaces of all cervical vertebral bodies from C2–C7 and then sums the segmental angles for an overall cervical curvature angle [14] (Fig. 1C). It has been suggested that the Cobb C1–C7 angle overestimates the CL, whereas the Cobb C2–C7 angle underestimates the CL, and that the Harrison method may provide the best estimate of lordosis [2,14]. Lastly, the Jackson physiological stress lines method requires drawing a parallel line to the posterior surface of the C7 and C2 vertebral bodies and measuring the angle between their intersection (Fig. 1B) [15]. The Cobb method remains the clinical mainstay of CL measurement due to its popularity, ease of use, and reliability between interpreters [16,17].

The normal value of CL is approximately $-40^{\circ}$ (by convention lordosis is reported as a negative angle), with a range from $-31^{\circ}$ to $-49^{\circ}$ [12]. Furthermore, the largest percentage of cervical lordosis in the standing position (approximately 85%) is localized at C1–C2 and relatively little lordosis exists in the lower cervical levels [12]. It is important to differentiate a still radiograph in standing position versus the normal motion of the cervical spine. Even though C1-2 have the largest lordosis angle on radiographs, anatomically it is the atlanto-occipital joint that provides most of the flexion-extension movement while C1-2 provide most of the axial motion in the cervical spine [18,19].

Translation of the cervical spine in the sagittal plane is measured through the cervical sagittal vertical axis (SVA), for which there are a few different methods of measurements. Both C2 SVA and C7 SVA have been used to define global sagittal alignment by measuring the distance between the C2 and C7 plumb line, from the posterior superior corner of the sacrum [2]. Cervical SVA (C2 SVA or cSVA) can also be defined regionally using the distance between a plumb line dropped from the center of C2 (or odontoid process) and the posterior superior aspect of C7 (C2–C7 SVA; Fig. 2). The average C2-C7 plumb line distance ranges from 15 to 17 ( ± - 11.udi2 mm) [12]. The gravity line is measured in the same way as the C7 SVA, however, the plumb line is drawn from the center of gravity (COG) of the head (COG SVA;(Fig. 2) [2,20]. In lateral radiographs, the COG of the head can be approximated by using the anterior portion of the external auditory canal as the initial point for the plumb line [21]. This method may also be applied regionally to C2 SVA instead of the C2 SVA (COG-C7 SVA). However, the C2 plumb line is especially clinically relevant as it has been directly correlated with neck pain and disability with a threshold of 37 mm of positive SVA [22].

When managing severe rigid cervical kyphotic deformities, measurement of horizontal gaze is especially useful as the loss of horizontal gaze has a significant impact on activities of daily living and quality of life [23]. The chin-brow vertical angle (CBVA) is the current method used to measure horizontal gaze and is defined as the angle subtended between a line drawn from the patient's chin to the brow and a vertical line (Fig. 2) [2,23]. Normal values for CBVA have not been characterized but the literature report that postoperative values of $+10^{\circ}$ to $-10^{\circ}$ have been well tolerated in patients [10, 23, 24] CBVA has been shown to be associated with positive postoperative outcomes, such as the improvement of gaze, ambulation, and activities of daily living [10, 23–25].

## 3. Cervical deformity

Deformity of the cervical spine can be categorized as either primary or secondary. Primary deformities are often congenital (congenital scoliosis, hemivertebrae, osteogenesis imperfecta, neurofibromatosis, etc.), while secondary cervical deformities in the sagittal plane arise from iatrogenic causes secondary to degenerative and inflammatory processes (rheumatoid arthritis, ankylosing spondylitis) (26).

Deformity of the spine occurs in both the sagittal and coronal planes. In general, sagittal plane deformities arise more frequently [27,26) and when surgically corrected, appear to play a more critical role in achieving better clinical outcomes [28].

Cervical kyphosis (CK) is by far the most prevalent cervical spine deformity and commonly presents with iatrogenic origins (e.g. post-laminectomy kyphosis) [27]. Once the onset of cervical kyphosis begins, the deformity tends to lead to compensatory mechanisms in other segments of the spine, as the entire spine acts as one unit [2].

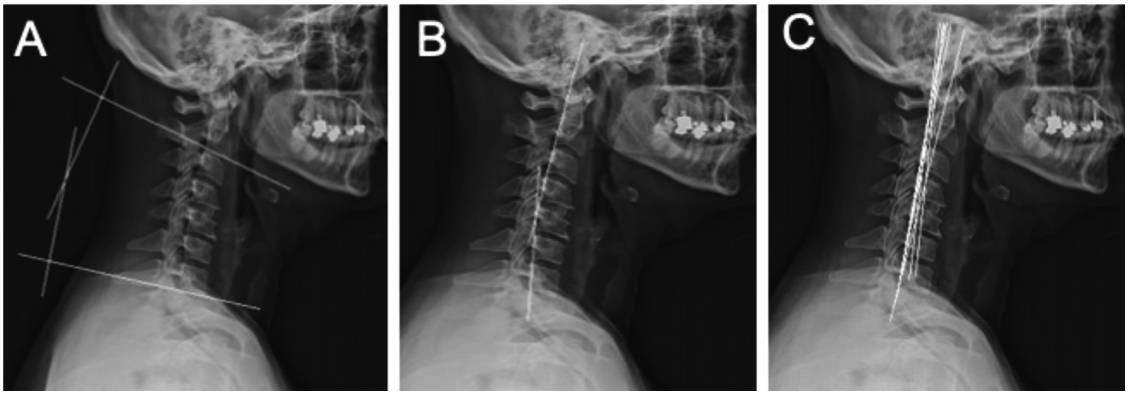


**Fig. 1.** Cervical lordosis calculation methods on lateral x-rays. A) Cobb method. B) Harrison method. C) Jackson method.

CK may also develop secondary to advanced degenerative disease, trauma, neoplastic disease, infection, and systemic arthritis such as ankylosing spondylitis or rheumatoid arthritis [26,27,29], or even be idiopathic.

Once cervical kyphosis is present, the biomechanical forces in the cervical spine create an additional load in the anterior vertebral body which could lead to disc degeneration and subsequently more kyphosis [18]. Nonetheless, cervical kyphosis may be present in asymptomatic individuals [30]. Therefore, careful evaluation of symptomatology and physical examination remain paramount when dealing with cervical deformity.

Despite being a common pathology, there is no accepted or widely used method for the classification of cervical deformity. Ames and colleagues [4] introduced a novel cervical spine deformity classification system based on clinical and radiographic parameters (Table 2). The classification system included a deformity descriptor and five modifiers that incorporate sagittal, regional, and global spinopelvic alignment and neurologic status. The descriptors included: C (cervical spine), CT (cervicothoracic junction), T (thoracic spine), S (coronal deformity) and CVJ (craniovertebral junction deformity). The modifiers included C2-C7 SVA, horizontal gaze (assessed by the CBVA), T1 slope (TS) minus C2-C7 lordosis (TS-CL), myelopathy measured by the modified Japanese Orthopedic Association score (mJOA scale score) and the Scoliosis Research Society (SRS) - Schwab classification for thoracolumbar deformity [4,31]. The inclusion of the mJOA score in this deformity classification is reflective of the frequent presence of myelopathy in the setting of cervical deformity. The study by Ramchandran et al. [32] used cervical parameters to define deformity, including the presence of at least one of the following values: cervical kyphosis (C2–7 sagittal Cobb angle > 10°), cervical scoliosis (C2–7 coronal Cobb angle > 10°), C2–7 sagittal vertical axis (cSVA) > 4 cm or chin-brow vertical angle (CBVA) > 25°.

Deformity can involve each segment of the cervical spine and the compensatory mechanisms that occur are mainly focused on maintaining the horizontal gaze [5,32,33]. In a cohort of patients with occipito-cervical (Occiput-C3) fusion, Matsubayashi et al. [33] found that in patients with C0-C2 kyphosis pre-operatively, the subaxial cervical spine compensates for the deformity of the upper cervical spine with hyperlordosis from C2-C7 and the entire cervical spine realigns against the T1 slope (T1 superior endplate and the angle formed with a horizontal line), which represents thoracolumbar spine alignment [34] to maintain a horizontal gaze. Interestingly, in this same cohort of OC fusion patients, post-surgical increases in occipitocervical angle lead to decreases in subaxial cervical lordosis to maintain overall cervical lordosis against the T1 slope [33].

Ramchandran et al. [32] found that patients with increasing cervical kyphosis demonstrated increases in the C2 slope. The C2 slope acts as an important link between the upper cervical and the subaxial cervical spine and, similar to the T1 slope, the C2 slope determines the amount of upper cervical lordosis required to maintain horizontal gaze [32]. Since the C2 slope is measured relative to a reference horizontal line, it decreases as the neck goes into hyperlordosis, which serves as a compensatory mechanism for subaxial kyphosis.

Mizutani et al. [35] found patients affected by cervical kyphosis

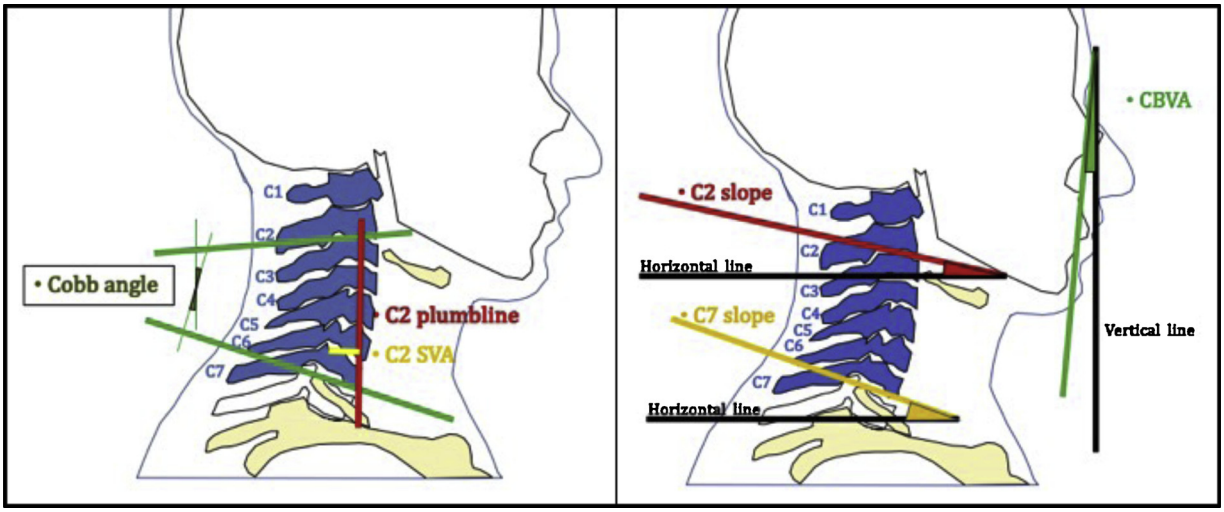


**Fig. 2.** Cervical sagittal parameters. Left) Cobb angle (green), C2 plumbline (red), C2-7 SVA (yellow). Right) Chin brow vertical angle (CBVA) (green), C2 slope (red), C7 slope (orange).

who present with discordant cervical parameters compared to the rest of the spine have different compensatory mechanisms involving the cervical spine itself (head-balanced type) and the thoraco-lumbar spine (trunk-balanced type) in order to try to preserve global spinal alignment.

Collectively, these prior studies emphasize the importance of the spine as a unit, in particular how the rest of the spinal segments (and the cervical spine itself) can adjust to compensate for a cervical deformity. The latter makes an evaluation of global spine alignment an important consideration in patients with cervical kyphosis.

## 4. Cervical myelopathy

Closely related to deformity is cervical myelopathy. While being a clinical diagnosis, magnetic resonance imaging (MRI) of the cervical is mandatory in the evaluation of these patients. Evidence of myelomalacia or focal intramedullary T2 hyperintensity at levels of highest compression are usually seen, signifying spinal cord edema. Clinical grading scales commonly used for evaluation include the Nurick Classification and the modified Japanese Orthopedic Association (mJOA) based on functional status. Cervical myelopathy has many different etiologies including spondylosis, tumors, vascular injuries, and Ossification of the Posterior Longitudinal Ligament (OPLL) [2,32]. Cervical spondylotic myelopathy (CSM) has been reported as the most common cause of spinal cord dysfunction in patients older than 55 years [36], although it can occur in a wide range of ages. Traditionally, the etiology of CSM has been described as a result of multilevel spondylosis in which osteophyte formation occurs as a result of degenerative changes in the discs [37,38]. However, less attention has been made to the fact that progressive cervical kyphosis has also been associated with myelopathy [5]. The mechanism behind the development of the myelopathy is kyphosis forcing the spinal cord against the vertebral bodies, inducing anterior cord pathology and increasing the longitudinal cord tension, due to the cord being tethered by the dentate ligaments and cervical nerve roots [1,39]. Over time, as the curve becomes more pronounced, the anterior and posterior margins of the cord compress and the lateral margins expand [40]. Cord tethering has been shown to cause an increase in intramedullary pressure leading to neuronal loss and demyelination [41,42]. Furthermore, the small feeder blood vessels on the cord become flattened, leading to reduced blood supply [40]. As the curve magnitude increases, these pathological changes become more pronounced, especially on the anterior side that is directly exposed to the mechanical compression [32,40]. As the cervical kyphosis progresses, so does the intramedullary pressure [43]. Given the close relationship between myelopathy and deformity, patients suffering from cervical deformity frequently experience the typical symptoms found in myelopathy: gait instability, neck pain, diminished hand dexterity, sphincter dysfunction, paresthesias, and extremity weakness [44,45,1,18,46]. Once patients begin to experience these symptoms of myelopathy, surgical management should be the priority with a goal of decompression of the neural elements [37,44] as surgery can stop the progression of neuro-functional decline [1].

## 5. Surgical management

Traditionally, patients with cervical spine deformity will undergo a period of non-surgical management such as physical therapy, oral pain medicines, spinal injections, and braces or collars. As mentioned above, patients with moderate to severe myelopathy and/or radiculopathy or other severe neurological deficits need surgery first rather than the usual non-surgical management route [37,44,1].

Despite advancement in techniques and our understanding of spinal deformity, the indications for surgical treatment of CK are not well defined [5]. However, there is an agreement in the literature to treat patients with progressive cervical myelopathy. Surgical treatment may be indicated in symptomatic patients with severe mechanical pain, progressive kyphotic deformity (“chin-on-chest” deformity), or disability, including dysphagia or difficulty maintaining horizontal forward gaze [18,29].

The goals of surgery in cervical spine deformity are: neural element decompression, correction of the deformity, restoration of horizontal gaze, restoration of normal cervical alignment, spinal stabilization with fusion, and avoidance of complications [2,18,29].

Many different surgical procedures and techniques exist for the treatment of cervical deformity, however, a general rule about the most appropriate surgical technique for each type of deformity remains a subject of study and should be determined on a case-by-case basis [18,47,48].

Surgical approaches are divided into three groups: anterior, posterior, and combined, all of which will be briefly discussed below.

### 5.1. Anterior

Anterior approaches are commonly performed for cervical disc disease. Anterior Cervical Discectomy and Fusion (ACDF) may be indicated for a fixed CK deformity without posterior ankylosis of the facet joints [29]. The reason is that significant fixed local or global kyphosis is a relative contraindication to posterior decompression and fusion since the spinal cord may remain “draped” over the anterior compressive elements following decompression without enough shift posteriorly providing no relief in symptoms [47,49]. Denaro and colleagues [50] recommended anterior decompression for patients with preoperative cervical kyphosis exceeding 13°. In patients with a lower degree of cervical kyphosis, the investigators performed posterior decompression, correction of the kyphosis, and fusion with improvement in alignment [51]. Many spine surgeons choose an anterior approach because it allows decompression through discectomy, correction of deformity, and spinal fusion (all of the main goals of cervical deformity treatment). The reconstruction of spine alignment using lordotic interbody spacers (cages) through an anterior approach may be necessary to restore the natural lordotic cervical curvature [52], as an exclusively posterior approach may not be sufficient to restore adequate cervical lordosis [47]. It is possible to treat multiple levels through discectomies and placement of interbody cages, thereby reducing CK or improving CL by 8-10° per cage on average (Fig. 3). Furthermore, Hitchon et al. recently evaluated patients with cervical myelopathy treated through anterior (ACDF) and posterior (laminectomy and instruemntion) approaches. Their group demonstrated that while both approaches were associated with significant improvement in multiple patient reported outcome measures, the anterior approaches was significantly associated with increasing C2-7 lordosis and shorter hospital stays versus the posterior approach group [53].

Another option is a combination of cervical corpectomy and discectomy. Corpectomy is only used at levels with retro-vertebral compression and discectomy is used at other levels combined with segmental fixation including plate and multilevel screws [29,54]. This avoids consecutive corpectomies and allows points of bony fixation for the screws, offering stability to the construct from bending forces [29]. Steinmetz et al. [27] concluded that an anterior approach was only safe and effective for the correction of postsurgical CK, while at the same time avoiding dorsal fusion and instrumentation in the majority of cases [27,29,55]. Herman and Sonntag [56] had reported on the successful outcomes and lower complication rate of multilevel corpectomies or discectomies together with anterior cervical plating in a cohort of patients with postlaminectomy kyphosis. They achieved a 20° correction of the sagittal angle through intraoperative axial traction and distraction, and most of the complications in this cohort were not related to the operative technique [56].

### 5.2. Posterior

Posterior surgical techniques for cervical deformity, myelopathy,

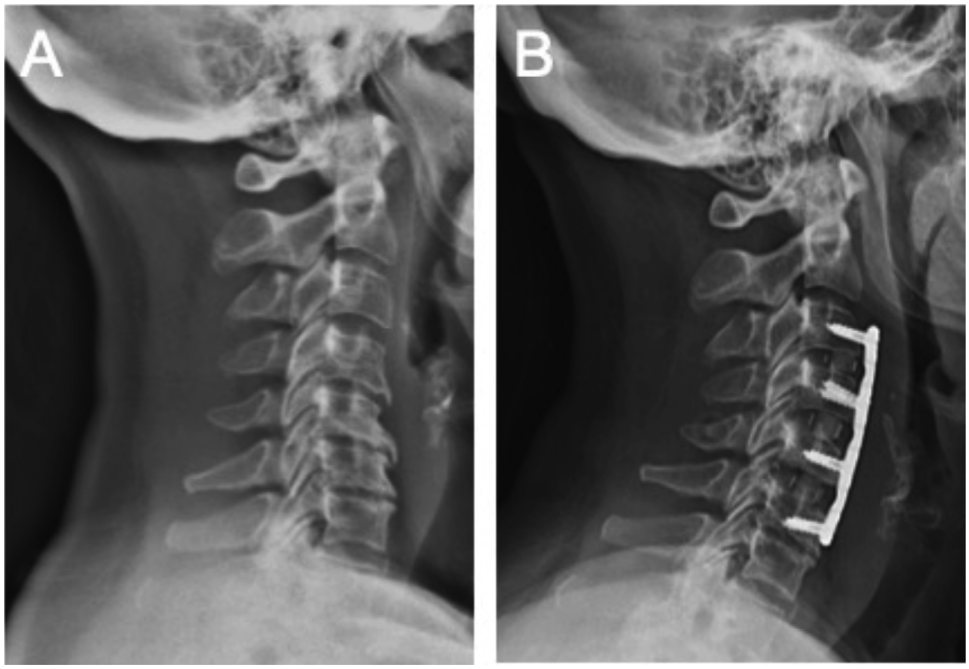


**Fig. 3.** A) Pre- and B) post-operative lateral cervical spine X-rays following multi-level anterior cervical discectomy and fusion with interbody grafts and plate.

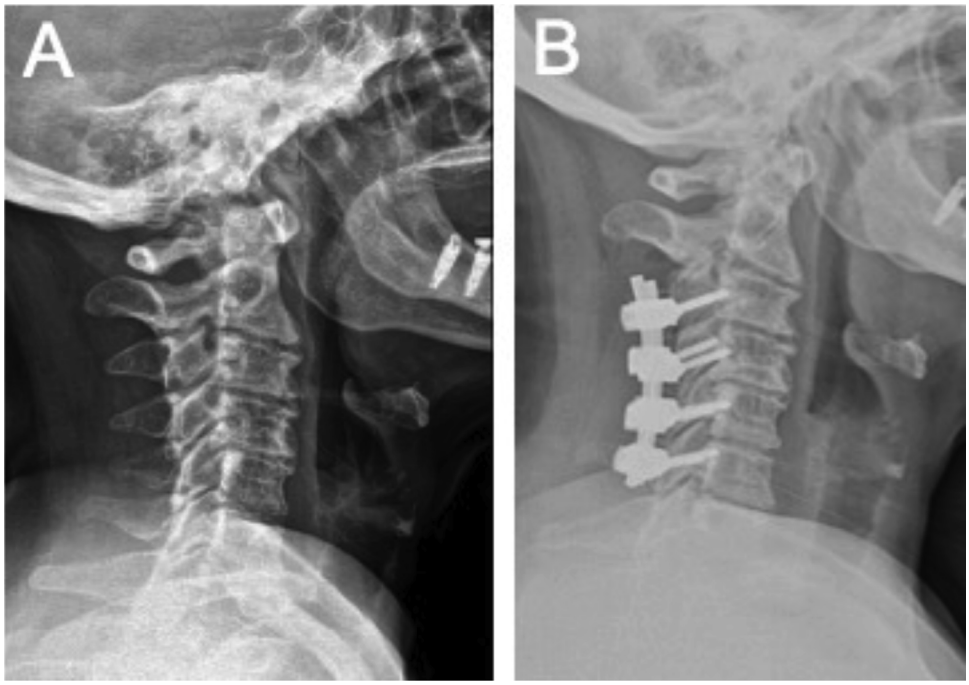


**Fig. 4.** A) Pre- and B) post-operative lateral cervical spine X-rays following posterior approach arthrodesis with instrumentation.

and sagittal alignment correction have evolved considerably over the past 40 years [47]. Historically, treatment for degenerative cervical myelopathy (DCM) often involved decompressive laminectomy alone. In general, decompressive laminectomy without fusion should be reserved for patients with preserved lordosis who may be poor candidates for fusion [47]. However, studies have demonstrated significant rates of progressive postoperative kyphosis and segmental instability [39,45,57], which may result in additional surgery requiring instrumentation and fusion. Given this factor, the use of laminectomy alone in the correction of cervical spinal deformity is now uncommonly used [48]. Thus, most surgeons prefer to perform laminectomy plus fusion [29] (Fig. 4). Instrumented fusion should be considered in patients with instability and correctable cervical kyphosis [47].

Another posterior cervical surgical technique is an expansive laminoplasty. In their analysis of 49 patients, Lee et al. [58] found laminoplasty can result in posterior cervical kyphosis with a relatively high probability. T1 slope can be a predictor of postoperative kyphotic changes in the cervical spine following laminoplasty, so careful consideration must be given to patients with a high T1 slope [58]. Compared to laminectomy and fusion, laminoplasty may be associated with higher rates of postoperative cervical kyphosis and segmental instability [59]. However, laminectomy and fusion change the normal cervical spine biomechanics, as axial and rotational forces are no longer physiologically distributed to subjacent spinal structures [60]. In

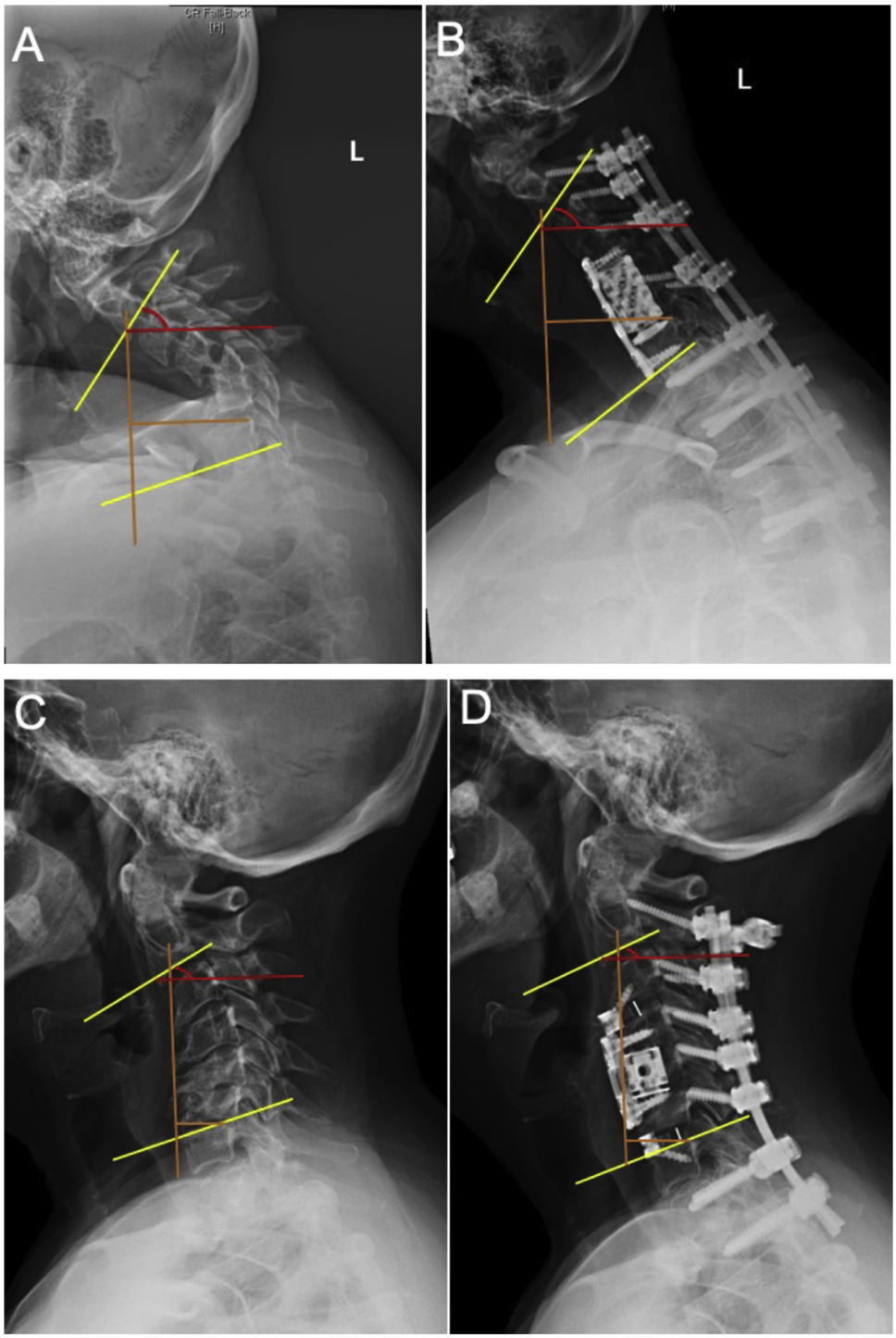


**Fig. 5.** Pre-operative and post-operative cervical X-rays following combined anterior-posterior approaches for deformity correction. A) Preoperatively the patient had a cobb angle of +40.6 degrees, C2 slope of 66.2 degrees, and a C2-7 SVA of 49.3 mm. B) Postoperatively, these measurements improved to +21.5 degrees, 53.9 degrees, and 48.7 mm, respectively. C) In a second patient, pre = operative cervical parameters for cobb angle, C2 slope, and C2-7 SVA were +20.7 degrees, 37.8 degrees, and 21.9 mm. D) Post-operatively, these measurements improved to +5.7 degrees, 28.9 degrees, and 19.2 mm, respectively. Legend: Yellow lines depict the cobb angle measured from inferior endplates of C2 and C7. The red line demonstrates the horizontal reference line and angle for the C2 slope, relative to the inferior endplate of C2 (yellow). The orange line demonstrates the C2 plumb line and C2-7 SVA measured from this plumb line to the superoposterior point of the C7 vertebral body.

contrast, expansive laminoplasty preserves motion with less substantial changes to natural cervical spine biomechanics, but may result in a less extensive cord decompression [61].

### 5.3. Combined

The combined anterior/posterior (or 360 degrees) method is a matter of surgeon preference. A combined strategy may be preferred if there is dorsal spinal compression and/or facet joint ankylosis, or if the cervical spine deformity correction cannot be achieved via an anterior approach only [29]. A posterior approach following an anterior approach has also been used to supplement the bone construct in patients with significant instability following anterior surgery (e.g. three level corpectomies) [29,46]. As mentioned above, the anterior approach is commonly used and is preferred as the first stage of a combined approach. With the anterior approach, discectomies and corpectomies (if needed) are performed followed by interbody grafting; subsequently, posterior instrumentation placement, osteotomies, and correction are performed [44,29] (Fig. 5).

The posterior–anterior sequence or a three-stage surgery (posterior-anterior-posterior) is used in circumstances where the kyphosis is too severe to perform the anterior approach in the first stage and where there is no ankylosis of the anterior column of the cervical spine ("flexible kyphosis"). The purpose of the anterior procedure in this

**Table 1**
Principal Radiographic cervical parameters.

| Sagittal Parameter | Definition |
|---|---|
| Cervical Lordosis (CL) | Cobb method: Angle between a line drawing the inferior endplate of C2 and another line drawing the inferior endplate of C7. Using (-) for lordosis and (+) for kyphosis |
| Cervical sagittal vertical axis (cSVA) | Horizontal offset between a chosen plumbline and the posterosuperior corner of C7 vertebral body. Measured using plumbline from barycenter of C1 (C1-C7 SVA), the barycenter of C2 (C2-C7 SVA), or the center of gravity of the head (COG) taken as a midpoint of the line between the 2 external auditory canals (COG-C7 SVA) |
| C2 slope | Angle between the C2 inferior endplate and horizontal reference line |
| C2 tilt | Angle between the posterior aspect of the C2 vertebral body and the vertical line |
| C7 slope | Angle between the C7 superior endplate and horizontal reference line |
| T1 slope | Angle between the T1 superior endplate and horizontal reference line |
| The chin-brow vertical angle (CBVA) | Angle subtended between a line drawn from the patients chin to brow and a vertical line. It is for measuring horizontal gaze |

Adapted from: "Importance of Sagittal Alignment of the Cervical Spine in the Management of Degenerative Cervical Myelopathy." by T.J Buell.

instance is to reconstruct the load-bearing capability of the spine [29,46].

Han et al [29] reviewed 12 studies of the surgical treatment of cervical deformity patients and found the combined anterior and posterior strategy resulted in a greater correction than the anterior strategy alone (30° of correction in the combined approach vs 23° in the anterior approach). However, the combined procedure involved a higher rate of postoperative neurological deterioration (i.e. radiculopathy), complications, revision surgery and mortality [62]. Postoperative quadriparesis was uncommon [63]. Finally, their results showed the combined procedure had a higher rate of fusion due to its ability to achieve anterior and posterior stabilization, yet caused a higher rate of need for gastrostomy/tracheostomy secondary to airway and swallowing dysfunctions [29].

## 6. Outcomes

Outcomes are measured through multiple scales and questionnaires such as the Neck Disability Index (NDI), 3-level EuroQol-5 Dimensions Questionnaire (EQ-5D-3 L), Visual Analogical Scale (VAS) for pain, modified Japanese Orthopaedic Association (mJOA) for myelopathy, and the 36-Item Short Form Health Survey (SF-36) [2,5,64]. The main goal of these questionnaires and scales is to assess, each in their own way, the patient's overall health-related quality of life (HRQOL). These scales and questionnaires are applied before and after surgery to assess improvement, stability, or decline in quality of life after different surgical procedures (in this case cervical spinal deformity correction). In addition to the surgical goals mentioned previously, improvement in the patient's quality of life should be part of the decision-making process for correcting cervical spine deformity.

Passias et al. [64] studied the relationship between myelopathy, surgical deformity correction, and patient- reported outcomes. They found a relationship between improvement in myelopathy and global sagittal realignment (C2-S1 SVA and C7-S1 SVA) and showed significant correlations with the overall improvement in EQ-5D-3 L and NDI scores (with diminished positive sagittal balance and myelopathy, and improved quality of life) [64]. These results highlight myelopathy improvement (mJOA improvement) as a key driver of patient-reported outcomes and confirm the importance of sagittal alignment in cervical deformity patients [29,47,64].

Furthermore, their data suggests improvement in myelopathy is more important to overall patient outcomes following cervical deformity corrective surgery than improvement in spinal alignment alone [64]. Shamji et al. [65] found that patients with preoperative lordosis showed better mJOA improvements than kyphotic patients after cervical spine deformity correction, which argues against a goal of just cervical spine realignment. Tang et al. [66] found a correlation between a high cSVA (> 40 mm) and worse outcomes on HRQOL questionnaires. The study by Passias et al. [64] did not find this correlation, but this could be partially explained by the fact that the study by Tang et al. [66] did not evaluate for myelopathy, which appears to be the leading factor in the cohort evaluated by Passias et al. [64].

On the other hand, Guerin et al. [67] found no relationship between patient-reported HRQOL outcomes and C2-C7 alignment. It is important to point out that there is no HRQOL instrument specific to cervical spine deformity and that the current questionnaires are an overall evaluation of the quality of life regardless of the spinal segment treated [64].

Further studies support the overall correction of spinal alignment and improvement in the quality of life. Mac-Thiong et al. [68] established correlations between positive C7-S1 SVA and worse Oswestry Disability Index (ODI) scores in a population of patients diagnosed with adult scoliosis. Radovanovic et al. [69] also found significant correlations between 1-year postoperative C7-S1 SVA and HRQOL outcomes of patients undergoing surgery for lumbar degenerative spondylolisthesis.

The study by Villavicencio et al. [70] reported higher SF-36 and NDI improvements in patients that underwent anterior discectomy and fusion with maintained or improved segmental alignment (alignment in the fused level) than those with worsened alignment, with a trend toward improvement in patients that had postoperative lordosis.

Although evidence exists on the outcomes of cervical spine deformity correction, the majority of these studies are retrospective in nature. Given the lack of a specific quality of life scale/questionnaire for the cervical spine, future studies should aim to address this gap in knowledge.

## 7. Key points

The following key points provide a framework that will allow spine surgeons to better evaluate and treat patients with cervical spine deformity.

- Patients presenting with signs and symptoms of cervical myelopathy should be evaluated with local AP and lateral cervical spine x-rays and three feet scoliosis films to assess spinal alignment, as well as CT and MRI scans of the cervical spine.
- Alignment: Different alignment parameters exist for the cervical spine (Table 1). These parameters should be measured and coupled with additional global spinal parameters (e.g C2-S1 plumb line) as the thoracic and lumbar spine may be compensating for cervical spine deformity. C2 SVA, COG SVA, C2-C7 SVA, CBVA, and T1 slope can further guide surgical correction.
- Patients presenting with progressive cervical myelopathy (evaluated by mJOA or Nurick scale) should be considered a priority for surgery. Surgical management of these patients should not be delayed by non-surgical management of their cervical spinal deformity.
- Surgery: different approaches to the cervical spine exist. The anterior approach is preferred in patients with rigid kyphosis. Consider a combined anterior-posterior approach for patients with fused facets, dorsal compression or those with poor bone quality. In cervical deformity with kyphosis (> 10°), posterior approaches (especially laminoplasty) alone should be avoided. Regardless, the surgeon should be familiar with both anterior and posterior approaches to

**Table 2**
Ames Classification of Cervical Deformity.

| CERVICAL DEFORMITY CLASSIFICATION | MODIFIERS |
|---|---|
| **Deformity Descriptor** | **C2-C7 SVA** |
| **C**: Primary Sagittal Deformity Apex in cervical spine | 0 : C2-C7 SVA < 40 mm |
| **CT**: Primary Sagittal Deformity Apex at Cervicothoracic Junction | 1 : C2-C7 SVA 40-80mm |
| **T**: Primary Sagittal Deformity in Thoracic spine | 2 : C2-C7 SVA > 80mm |
| **S**: Primary Coronal Deformity (C2-C7 Cobb angle > 15°) | **Horizontal Gaze** |
| **CVJ**: Primary Craniovertebral Junction Deformity | 0 : CBVA 1°-10° |
| | 1 : CBVA -10°-0° or 11°-25° |
| | 2 : CBVA < -10° or > 25° |
| | **Cervical Lordosis minus T1 slope** |
| | 0 : TS-CL < 15° |
| | 1 : TS-CL 15°-20° |
| | 2 : TS-CL > 20° |
| | **Myelopathy** |
| | 0 : mJOA = 18 (None) |
| | 1 : mJOA = 15-17 (Mild) |
| | 2 : mJOA = 12-14 (Moderate) |
| | 3 : mJOA = < 12 (Severe) |
| | **SRS Schwab Classification** |
| | T, L,D or N Curve type |
| | 0, + or + + PI-LL |
| | 0, + or + + Pelvic Tilt |
| | 0, + or + + C7-S1 SVA |

Adapted from Ames CP, Smith JS, Eastlack R et al (2015) Reliability assessment of a novel cervical spine deformity classification system. J Neurosurg Spine 23(6):673–683).

the cervical spine while treating these patients and ultimately select the approach that will limit complications and further morbidity.

## 8. Conclusion

The primary goals of deformity correction are first goal to achieve optimal decompression of neural elements when compressive pathology is present. The second goal, closely related to the first, is to restore cervical spine alignment to a neutral (in the case of severe kyphosis) or lordotic angle. Improvement in the horizontal gaze is closely tied to improvement in cervical alignment. Overcorrection should be avoided to prevent new neurological deficits (e.g post-surgical radiculopathy). The current scientific literature agrees that decompression alone is inadequate to achieve long term improvement of myelopathy and neck pain in patients with sagittal and/or coronal cervical imbalances. The third goal of surgery is to improve symptoms myelopathy via decompression and then aggressive postoperative rehabilitation. Improvement in myelopathy is correlated with postoperative improvement in the patient's quality of life.

## Disclosures

FT, MJA, LW, SF, CC, IH: Nothing to disclose. AAB: Declares royalties from Thieme Publishers, is a consultant for DePuy-Synthes and Stryker.

## Declaration of Competing Interest

The authors declare that they have no conflicts of interest.

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