Part I

Techniques for Cervical Spinal Deformity Correction
1 Cervical Sagittal Balance

Yahya Güvenç, Onur Yaman, and Salman Sharif

Introduction

Humans are characterized by bipedalism, but this is achieved by keeping the body in balance. The spine performs an essential function in maintaining balance. Humans developed cervical curvature, lumbar lordosis, thoracic kyphosis, and horizontal gaze to maintain balance. It is crucial to analyze the matter both statically and dynamically to understand balance. There are differences between the balance people keep while standing and the balance conditions while moving. In addition, the healthy spine and the unhealthy spine show differences in the mechanisms while maintaining balance. To maintain the balance, we need to define the morphological criteria and then analyze the compensation phenomena, physiological or pathological. For this purpose, we should know that we need to evaluate the spine as a whole. Changes in the cervical, thoracic, and lumbar regions affect the global balance of the spine. Therefore, in surgical procedures for any spine region, we need to examine the morphological features. Therefore, cervical measurements should be made for surgical planning before any intervention in the cervical region.

Cervical sagittal balance is an important issue that should be considered in operations.

Some studies show that preoperative cervical kyphosis with sagittal imbalance has worse postoperative outcomes. Kyphotic deformity, one of the types of cervical malalignment, usually occurs after postlaminectomy. Kyphosis causes increased neck pain, intradiskal pressure, degeneration, intraspinal canal pressure, and resulting myelomalacia. Therefore, surgical correction of patients should target cervical lordosis with global spinal balance.1

Cervical sagittal balance is an essential part of global spinal sagittal balance. The cervical spine is an effective part for compensating for global sagittal balance to maintain horizontal gaze. Cervical sagittal balance is directly related to health quality of life factors. In cervical fusion, this must be considered when determining the ideal alignment for permanent fixation.

In spinal alignment, the cervical, thoracic, lumbar, and pelvic regions are interconnected. When there is a deterioration in these regions, other areas compensate for this situation. In the degenerative spine with imbalance, compensatory mechanisms work for maintaining the balance. When there is a decrease in the lumbar lordosis of the patients, there will be an anterior malposition; to correct this, there will be an increase in thoracic kyphosis and cervical lordosis due to compensatory mechanisms. When cervical kyphosis occurs, the compensatory mechanism increases lumbar lordosis and decreases thoracic kyphosis. The cervical spine lordosis will change to maintain a horizontal perspective and the position of the head in the vertical plane relative to the body. If there is a severe primary cervical deformity, the lumbar spine and pelvis will be involved in the compensatory mechanism. Therefore, when planning deformity surgery, we need to measure cervical deformation and compensatory changes.

Definitions

There are some cervical spine sagittal alignment parameters. Some are commonly used parameters; others are newly proposed parameters (Table 1.1).

There are many values close to each other in the literature regarding “normal” cervical parameters. Therefore, there is no definite value for each angle. However, there is a range of values that can be common for cervical parameters. Many studies in the literature conducted in the asymptomatic population show differences in normal cervical angle result in each study (Table 1.2).2–8 The biggest reason for this is that we are measuring a dynamic spine. Although these measurements vary, the mean values are close to each other. Therefore, these mean values can give us an idea of normal cervical spinal parameters (Table 1.2).2–8

Table 1.1 Cervical sagittal alignment parameters

<table>
<thead>
<tr>
<th>Commonly used cervical spine parameters</th>
<th>Newly proposed cervical spine parameters</th>
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<tbody>
<tr>
<td>C0–C2 lordosis</td>
<td>Cranial tilt</td>
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<tr>
<td>C2–C7 lordosis</td>
<td>Neck tilt</td>
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<tr>
<td>C2–C7 SVA</td>
<td>Cervical tilt</td>
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<tr>
<td>CBVA</td>
<td>EAM–C7 sagittal vertical axis</td>
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<tr>
<td>T1 slope</td>
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<td>TIA</td>
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Abbreviations: CBVA, chin brow vertical angle; EAM, external auditory meatus; SVA, sagittal vertical axis; TIA, thoracic inlet angle.
Table 1.2  Cervical parameters of asymptomatic individuals in some studies in the literature

<table>
<thead>
<tr>
<th></th>
<th>C0–C2</th>
<th>C1–C2</th>
<th>C2–C7</th>
<th>C0–C7</th>
<th>SVA C0–C7</th>
<th>C7 S</th>
<th>T1 S</th>
<th>T1A</th>
<th>Neck tilt</th>
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<tbody>
<tr>
<td>Hardacker et al7</td>
<td>–31.9 ± 7.0°</td>
<td></td>
<td></td>
<td></td>
<td>–40.0 ± 9.7°</td>
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<tr>
<td>Guo et al2</td>
<td>–16.3 ± 7.0° (female)</td>
<td>–28.2 ± 4.0° (females),</td>
<td>–12.7 ± 6.6° (female),</td>
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<tr>
<td></td>
<td>–14.9 ± 6.5° (males)</td>
<td>–26.4 ± 4.6° (males)</td>
<td>–16.3 ± 7.3° (male)</td>
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<tr>
<td>Lee et al8</td>
<td>–22.4 ± 8.5°</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>20.7 ± 11.7 mm</td>
<td>19.6 ± 8.8°</td>
<td>25.7 ± 6.4°</td>
<td>69.5 ± 8.6°</td>
</tr>
<tr>
<td>Núñez-Pereira et al3</td>
<td>–12.7 ± 6.9°</td>
<td>–20.8 ± 7.3°</td>
<td>–15.8 ± 13.2°</td>
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<tr>
<td>Hey et al5</td>
<td>–27.4 ± 9.4°</td>
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<tr>
<td>Chen et al6</td>
<td>–26.2 ± 7.2°</td>
<td>–12.1 ± 10.6°</td>
<td>19.6 ± 13.5°</td>
<td></td>
<td></td>
<td>23 ± 7.1°</td>
<td>62.4 ± 8.5°</td>
<td>39.4 ± 8.4°</td>
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</table>

Cervical Lordosis

There are some ways to measure cervical lordosis. The Cobb method, the Ishihara index method, Harrison’s posterior tangent method, and Jackson physiological stress lines are the most known methods.9–11 The Cobb method (mCM) is most frequently used in practical applications. A study showed C1 to C7 lordosis of –39 ± 9 degrees in adults without neck symptoms.7 Cervical lordosis is evaluated in two different subgroups because the mobility in the cervical region shows differences between segments. The C1–C2 region where the movement is high is responsible for 77% of the cervical lordosis, and the remaining 23% occurs at C2–C7 level where the movement is less.10

The results of some studies have shown that the cervical lordosis (C0–C7) is around 30 degrees.12–14 Posture and thoracic kyphosis affect cervical lordosis. Therefore, it is recommended to take X-ray images when the patient is standing. As we get older, thoracic kyphosis increases, and lumbar lordosis decreases. Due to this change, compensation mechanisms come into play in cervical lordosis to provide a horizontal view.

- **Cervical lordosis (C0–C2):** This angle is formed by the McGregor’s line and the inferior end plate of C2 (Fig. 1.1). C0–C2 angle ranges from –12.3 to –27.4 degrees (Table 1.2).
- **Cervical lordosis (C2–C7):** This angle is formed by the inferior end plate of C2 and the superior end plate of C7 (Fig. 1.2). C2–C7 angle ranges from –12.1 to –16.3 degrees (Table 1.2).
- **Cervical lordosis (C0–C7):** The angle is formed by the McGregor’s line and the superior end plate of C7 (Fig. 1.3). C0–C7 angle ranges from –30.0 to –40.3 degrees (Table 1.2).

C2–C7 Sagittal Vertical Axis (SVA)

The horizontal distance between a plumb line drawn perpendicularly from the midpoint of the C2 vertebral body and the upper posterior corner of the C7 vertebral body is defined as the SVA (Fig. 1.4). C2–C7 SVA measures cervical sagittal alignment, and this angle is correlated with...
health-related quality of life. A study found a mean C2–C7 SVA of 4.74 mm in asymptomatic persons. Iyer et al showed that C2–C7 SVA was 21.3 mm in 120 asymptomatic persons. Tang et al examined the patients who had undergone multilevel posterior cervical fusion surgery and observed that when C2–C7 SVA is >40 mm, there was an increase in the disability.

Chin Brow Vertical Angle (CBVA)

The angle between the line drawn from the chin to the forehead and the vertical is called the chin brow vertical angle (CBVA). This angle is used to determine horizontal gaze (Fig. 1.5). CBVA of a patient with ankylosing spondylitis who has been operated on is shown in Figs. 1.6 and 1.7. CBVA changes according to head position. For example, CBVA is positive when the head is directed downward; CBVA is negative when the head is directed upwards; when the head is in the neutral position, CBVA is zero. However, in some cervical deformities, the movements of the head are restricted, and CBVA goes outside the normal limits.

Suk et al suggested that CBVA should be within the range of –10 degrees to +10 degrees for providing optimal horizontal gaze when correcting the kyphotic deformity in ankylosing spondylitis.
The concepts of T1 slope (T1S) and TIA are similar to the relationship between pelvic tilt, pelvic incidence, and sacral slope in the lumbosacral region. TIA, T1S, and neck tilt used to describe cervical spinal deformities are also used in surgical planning and affect clinical outcomes.

**T1 Slope (T1S)**

T1S is the angle between the superior end plate of T1 and horizontal (Fig. 1.8a, b). T1S is associated with the sagittal alignment of the cervical region. In addition, the T1S reflects the degree of thoracic kyphosis. T1S angle ranges from 17.4 to 25.7 degrees (Table 1.2).

**Thoracic Inlet Angle (TIA), T1S, and Neck Tilt**

The concepts of T1 slope (T1S) and TIA are similar to the relationship between pelvic tilt, pelvic incidence, and sacral slope in the lumbosacral region. TIA, T1S, and neck tilt used to describe cervical spinal deformities are also used in surgical planning and affect clinical outcomes.
TIA (Figs. 1.9a, b, and 1.10). TIA determines cervical lordosis. A patient with high TIA has increased cervical lordosis. Lee et al showed that T1S and cervical lordosis are correlated as a compensation mechanism. Their study showed that the horizontal gaze was preserved at around 44 degrees neck tilt by increasing TIA, T1S, and cervical lordosis.⁸

Cervical Tilt

It is the angle between a line at 90 degrees to the T1 superior end plate and a line from the middle of the T1 superior end plate to the tip of the dens (Fig. 1.11). The angle between this same line and vertical is called cranial tilt (Fig. 1.12). The cranial and cervical tilt angles equal the T1S angle. The cervical tilt angle ranges from 39.4 to 43.7 degrees (Table 1.2).

Neck Tilt

Neck tilt is a cervical parameter. It describes the angle between vertical and a line from the middle of the T1 inferior end plate and the upper end of the sternum (Fig. 1.13).

Recent studies have defined cervical deformities by using cervical parameters. In these studies, Smith et al defined cervical deformity as C2–C7 kyphosis of >10 degrees and C2–C7 SVA of >4 cm.¹⁸ In addition, Passias et al added other definitions for deformity in their studies. Cervical deformity concepts have been evaluated from many perspectives. According to this study, cervical parameters play a decisive role in defining cervical deformities. For example, when describing cervical kyphosis, it was stated that the C2–C7 Cobb angle should be >10 degrees. In addition, the coronal Cobb angle should be considered when defining cervical scoliosis, and it is indicated in cases where the coronal Cobb angle is >10 degrees. Positive cervical sagittal imbalance is when C2–C7 SVA is >4 cm or T1S–cervical lordosis is >10 degrees. When evaluating the horizontal gaze disorder, we pay attention to cases where the vertical angle of the chin–eyebrow is >25 degrees.¹⁸,²⁰
Fig. 1.9 (a, b) Measurement of thoracic inlet angle.

Fig. 1.10 Measurement of thoracic inlet angle and T1 slope.

Fig. 1.11 Measurement of cervical tilt angle.
Chapter 1

Key Points

• Cervical sagittal balance is an essential component of global spinal balance. Therefore, it should be evaluated together with the global spinal balance.

• The cervical spine may change in alignment to maintain a horizontal gaze. It does this with compensation mechanisms.

• Cervical lordosis (C2–C7), T1 offset, and C2–C7 SVA are the most important considerations during sagittal reconstruction.

• Cervical parameters affect clinical outcomes. Cervical parameters are necessary for surgical planning, and they will help determine the instrument level. Osteotomy planning is done according to cervical parameter results.

References


Fig. 1.12 Measurement of cranial tilt angle.

Fig. 1.13 Measurement of neck tilt angle.