

Peer review file

Article information: <https://dx.doi.org/10.21037/jss-21-54>

Reviewer A

Comment 1: The authors present a review of cervical kyphosis. There i a brief mention of the etiologies of cervical kyphosis and a more detailed discussion of treatment options. Kyphosis from trauma, infection, neoplasm, and congenital anomalies are not mentioned and the authors should state that these were excluded.

Reply 1: We corrected as suggested. (Page 4, line 9-11)

Change in the text: Post-laminectomy kyphosis, degenerative kyphosis, kyphosis secondary to ankylosing spondylitis are highlighted in this article as they are more common than kyphosis from trauma, infection, neoplasm, and congenital anomalies.

Comment 2: T1 slope is not depicted in a Figure and should be.

Reply 2: T1 slope is shown in Figure 6.

Change in the text: none

Comment 3: I am not certain that the ACDF and corpectomy illustrations add much to the work and these should be deleted.

Reply 3: We deleted Figures 8 and 9.

Change in the text: Figures 8 and 9 are deleted.

Reviewer B

Major concern

Comment 1: Recent articles highlight the importance of global sagittal alignment in treating cervical kyphosis. There exists a close relationship between cervical and thoracolumbar spine. Furthermore, 53% of adult patients with a thoracolumbar deformity have a concomitant cervical deformity (1, 2). To preserve normal horizontal gaze, thoracic kyphosis and thoracolumbar alignment directly affect the cervical alignment (1). Though the manuscript suggests 36-inch radiographs as a method to

assess global spinal alignment, it did not elaborate on the recent trends in the importance of global sagittal alignment including lower extremities and why it is necessary to assess global spinal alignment.

Reply 1: We added importance of whole spine evaluation in “Radiographic evaluation” section. (Page 6, line 21-26)

Change in the text:

Standard evaluation includes static and dynamic cervical radiographs. Standing anteroposterior and lateral 36-inch radiographs are also useful to assess global spinal alignment (29-33) as a close relationship exists between the cervical and thoracolumbar spine. Cervical kyphosis may be primary or reciprocal due to thoracolumbar deformity. Thoracic kyphosis and thoracolumbar alignment directly affect the cervical alignment to maintain horizontal gaze (34). Furthermore, 53% of adult patients with a thoracolumbar deformity have a concomitant cervical kyphosis (35).

Comment 2: In the radiographic evaluation section, the authors asserted that radiographic parameters in the cervical spine that affect health-related quality of life have not been well defined. However, there are studies demonstrating C2-C7 sagittal vertical axis or T1 slope related to patient outcomes or HRQOL (3-5). The authors referred to the same study in line 167 (5).

Reply 2: I corrected as suggested. (Page 7, line 7-15)

Change in the text: Unlike spinopelvic parameters for thoracolumbar deformity, radiographic parameters in the cervical spine that affect health-related quality of life (HRQOL) have not been well defined (36, 37). However, there are a few studies that have shown parameters associated with HRQOL. Oe et al. investigated cervical alignment in volunteers aged over 50 and demonstrated that C2-C7 SVA, T1S, and T1S-CL negatively influenced EQ-5D(38). Hyung et al. showed that C2-C7 SVA > 40.8 mm and 70.6 mm, and T1S-CL > 20° and 25° were associated with moderate and severe disability following multilevel posterior cervical fusion surgery, respectively (39). A C2-7 SVA > 40 mm was reported to be correlated with increased disability in patients undergoing posterior cervical fusion (40).

Comment 3: The biomechanics section in this study is mostly about the basis of the cervical spine related to cervical deformity. However, the content is not sufficient to

support the authors' point of view throughout the manuscript. The movement of the center of mass of the cranium and the change in instantaneous axis of rotation is related to the development and aggravation of cervical kyphosis (6). The biomechanics of cervical deformity cannot be explained simply with axial loading as the authors have illustrated in the manuscript, as in line 81 (weight shift forward), line 121 (forward shift of the head), line 135, or 137 ('cone of balance'). Adding more information on biomechanics would be helpful in understanding the manuscript. Moreover, previous research on axial load was measured in the superior articular surfaces, not the whole posterior elements as the authors have defined in the manuscript (7).

Reply 3: We have added more information in Biomechanics section. (Page 4, line 1-5)

Change in the text: In the healthy cervical spine, axial loads are applied along the instantaneous axis of rotation (IAR). The loads are supported along the anterior column of the spine. With aging of spine, the disc continues to lose height and lordosis is reduced. The axial force is offset from the IAR, producing a greater moment arm at the point of rotation. Greater loss of lordosis increases the moment arm, worsening kyphotic deformity.

Minor concern

Comment 4: There is a conflation of terminology, cervical kyphosis, and cervical deformity.

Reply 4: We corrected as suggested. (Throughout the manuscript)

Change in the text: throughout the manuscript

Comment 5: 'Biomechanics of the cervical spine' in line 61 would be a more clear title.

Reply 5: We added more information in this section as you suggested, and we left the title as it was.

Change in the text: None

Comment 6: 'Iatrogenic' would be a more fitting title since the paragraph contains procedures other than laminectomy, such as laminoplasty.

Reply 6: We think kyphosis following laminoplasty is still iatrogenic as kyphosis may come from extensor muscle failure, facet capsule violation, and so forth.

Change in the text: None

Comment 7: The referenced article in line 85 states ‘anterior vertebral body of children have not completed ossification and is composed of cartilaginous portion, which leads to wedging’ under cumulative stress. The current sentence ‘anterior vertebral bodies - osteophytic’ in the manuscript could be misleading to the readers.

Reply 7: We corrected as suggested. (Page 4, line 22-23)

Change in the text: the anterior vertebral bodies in children are less ossified and composed of cartilaginous portion, leading to wedging under cumulative stress.

Comment 8: The sentence in line 98 seems fragmented. Do the authors mean ‘Laminoplasty is the most widely accepted method and has achieved improved clinical outcomes without decreasing cervical lordosis and without adding significant operative time, and without increasing morbidity compared with laminectomy and fusion’?

Reply 8: We revised as follows. (Page 5, line 5-8)

Change in the text: Laminoplasty is the most widely accepted method and has achieved improved clinical outcomes without decreasing cervical lordosis and without adding significant operative time and morbidity compared with laminectomy and fusion

Comment 9: Additional inquiries on abbreviations and minor grammatical errors

Reply 9: We corrected as follows.

Change in the text:

1. Proximal junctional failure (PJK) in line 112

=>corrected to Proximal junctional kyphosis (Page 5, line 22)

2. mJOA (modified Japanese Orthopaedic Association) score in line 197

=>myelopathy based on modified Japanese Orthopaedic Association score (Page 9, line 6)

3. SPO (Smith-Petersen osteotomy) was used in line 224, whereas posterior column osteotomies (PCO) was previously used in line 204

=>PCO was revised to SPO (Page 9, line 25-26)

4. Should use lower case letters in line 196 (horizontal gaze, myelopathy), line 204(posterior column osteotomies)

=>revised as suggested

5. Figure 12 seems to be a schema of pedicle subtraction osteotomy, not SPO

=>SPO is revised to PSO (Page 16, line 16)

1. Diebo BG, Challier V, Henry JK, Oren JH, Spiegel MA, Vira S, et al. Predicting Cervical Alignment Required to Maintain Horizontal Gaze Based on Global Spinal Alignment. *Spine (Phila Pa 1976)*. 2016;41(23):1795-800.
2. Smith JS, Lafage V, Schwab FJ, Shaffrey CI, Protopsaltis T, Klineberg E, et al. Prevalence and type of cervical deformity among 470 adults with thoracolumbar deformity. *Spine (Phila Pa 1976)*. 2014;39(17):E1001-9.
3. Hyun SJ, Han S, Kim KJ, Jahng TA, Kim HJ. Assessment of T1 Slope Minus Cervical Lordosis and C2-7 Sagittal Vertical Axis Criteria of a Cervical Spine Deformity Classification System Using Long-Term Follow-up Data After Multilevel Posterior Cervical Fusion Surgery. *Oper Neurosurg (Hagerstown)*. 2019;16(1):20-6.
4. Oe S, Togawa D, Nakai K, Yamada T, Arima H, Banno T, et al. The Influence of Age and Sex on Cervical Spinal Alignment Among Volunteers Aged Over 50. *Spine (Phila Pa 1976)*. 2015;40(19):1487-94.
5. Tang JA, Scheer JK, Smith JS, Deviren V, Bess S, Hart RA, et al. The impact of standing regional cervical sagittal alignment on outcomes in posterior cervical fusion surgery. *Neurosurgery*. 2015;76 Suppl 1:S14-21; discussion S.
6. Ferrara LA. The biomechanics of cervical spondylosis. *Adv Orthop*. 2012;2012:493605.
7. Pal GP, Sherk HH. The vertical stability of the cervical spine. *Spine (Phila Pa 1976)*. 1988;13(5):447-9.

Reviewer C

Comment 1: The authors state that full-spine X-rays as necessary to evaluate cervical spine but should specifically note the reason for this is to differentiate between the cervical deformities that may be 'primary' or 'reciprocal' (compensations from lower spine deformities).

Reply 1: We added importance of whole spine evaluation in “Radiographic evaluation” section. (Page 6, line 21-26)

Change in the text: Standard evaluation includes static and dynamic cervical radiographs. Standing anteroposterior and lateral 36-inch radiographs are also useful to assess global spinal alignment (29-33) as there exists a close relationship between cervical and thoracolumbar spine. Cervical kyphosis could be primary or reciprocal due to thoracolumbar deformity. Thoracic kyphosis and thoracolumbar alignment directly affect the cervical alignment to maintain horizontal gaze (34). Furthermore, 53% of adult patients with a thoracolumbar deformity have a concomitant cervical deformity (35).

Comment 2: In stating that full-spine X-rays are necessary, it is also important to indicate that dedicated cervical X-rays are also necessary as full-spine X-rays project the cervical spine as straighter possibly affecting surgical planning from projection distortion.

Reply 2: We revised the radiographic evaluation section accordingly. (Page 6, line 27-28)

Change in the text: It is optimal to obtain both dedicated cervical and 36-inch radiographs because clavicle position caused a decrease in the T1-slope (36, 37).

Comment 3: The high cervical angle (C0-C2) is commonly used to quantify an inverse relation between the lower cervical angle (C2-C7), this needs to be included.

Reply 3: We added high cervical angle (C0-C2) in the radiographic evaluation section. (Page 7, line 25-27)

Change in the text: High cervical angle is also commonly used, which is measured by the angle between the McGregor line and the lower C2 endplate. This angle has an average value of 15.81° and work with CL inversely.

Comment 4: It is mentioned that a cSVA $>40\text{mm}$ is associated with worse clinical outcome (lines 167,168), however, some have found tighter relationships such as Ajello et al. World Neurosurgery, 2017 founds $<25\text{mm}$ was associated with a better clinical outcome - this should be added to state this may be more ideal than the standard acceptance of $<40\text{mm}$ cSVA post-surgical goal.

Reply 4: We added the findings from this paper. (Page 7, line 15-17)

Change in the text: Ajello et al. showed that a C2-C7 SVA $< 25\text{ mm}$ and CL/C7 slope $>$

0.7 were correlated with positive outcomes following anterior cervical arthrodesis (44).

Comment 5: The authors mention that "unlike spinopelvic parameters for thoracolumbar deformity, radiographic parameters in the cervical spine that affect health-related quality of life have not been well defined" (lines 153-155). The authors should note that efforts are being made to better determine patient-specific lordosis based on relationships between radiographical parameters (e.g. Ajello et al. 2017 found patients with a CL/C7 slope greater than 0.7 had better surgical outcomes).

Reply 5: We added the relationship between HRQOL and cervical parameters from several papers. (Page 7, line 7-17)

Change in the text: Unlike spinopelvic parameters for thoracolumbar deformity, radiographic parameters in the cervical spine that affect health-related quality of life (HRQOL) have not been well defined (38, 39), however, a few studies have shown parameters related to HRQOL. Oe et al. investigated cervical alignment in volunteers aged over 50 and demonstrated that C2-C7 SVA, T1S, and T1S-CL negatively influenced EQ-5D(40). Hyung et al. showed that C2-C7 SVA > 40.8 mm and 70.6 mm, and T1S-CL > 20° and 25° were associated with moderate and severe disability following multilevel posterior cervical fusion surgery, respectively (41). A C2-7 SVA > 40 mm was reported to be correlated with increased disability in patients undergoing posterior cervical fusion (42). Ajello et al. showed that a C2-C7 SVA < 25 mm and CL/C7 slope > 0.7 were correlated with positive outcomes following anterior cervical arthrodesis (43).

Comment 6: Thoracic inlet angle - This needs to be mentioned as it is an important parameter that is patient-specific and will undoubtedly lead to a better understanding of the cervical parameter relationships and patient-specific lordosis determination (Lee et al. J Spinal Disord Tech, 2012).

Reply 6: We added TIA in the radiographic evaluation section. (Page 7, line 10-13)

Change in the text: Similarly, thoracic inlet angle (TIA) is another patient-specific parameter to predict physiological alignment of the cervical spine. Thoracic Inlet Angle TIA is measured by the angle subtended by a line drawn perpendicular through the center of the superior endplate of T1 and a line from the midpoint of the superior endplate of T1 to the apex of the manubrium.

Comment 7: Lines 159-160 - Authors discuss C2-C7 Cobb method of lordosis measurement. Should be mentioned that other methods are available and may have less standard error of measurement such as Harrison posterior tangent method, and that surgeons should move towards better measurement methods as the literature changes. Also, the posterior tangent method is in line with mechanical engineering analysis as it measures with lines contiguous with the column axis and the Cobb angle is along the endplates that crosses the long axis (Harrison DE, Harrison DD, Cailliet R, Troyanovich SJ, Janik TJ, Holland B. Cobb method or Harrison posterior tangent method: which to choose for lateral cervical radiographic analysis. *Spine (Phila Pa 1976)*. 2000 Aug 15;25(16):2072-8).

Reply 7: We corrected as suggested. (Page 7, line 20-24)

Change in the text: Harrison posterior tangent method is another measurement method for cervical lordosis that may have less standard error of measurement, in which cervical lordosis is measured by the angle between tangents drawn at the posterior body margins of C2 and C7. Surgeons should move towards better measurement methods as the literature changes.

Comment 8: No discussion about alternative/supportive treatments. For patients who cannot have surgery or are not surgical candidates, many do not know what to recommend. There is a non-surgical method to increase cervical lordosis termed 'extension traction'. Many RCTs have shown this to be safe and effective. (e.g. Moustafa IM, Diab AA, Hegazy F, Harrison DE. Does improvement towards a normal cervical sagittal configuration aid in the management of cervical myofascial pain syndrome: a 1- year randomized controlled trial. *BMC Musculoskelet Disord*. 2018 Nov 12;19(1):396; Moustafa IM, Diab A, Shousha T, Harrison DE. Does restoration of sagittal cervical alignment improve cervicogenic headache pain and disability: A 2-year pilot randomized controlled trial. *Heliyon*. 2021 Mar 15;7(3):e06467).

Reply 8: We added “Non-surgical treatment” section. (Page 9, line 8-15)

Change in the text:

Non-surgical Treatment

Non-surgical treatment is indicated for mild cervical kyphosis and patients who cannot have surgery. There is a scarce evidence in the effectiveness of conservative treatment

for cervical kyphosis. Moustafa et al. conducted a randomized control trial to examine if denneroll cervical traction (Denneroll Industries, Sydney, Australia; <http://www.denneroll.com>) improved cervical kyphosis. After 10 weeks of the intervention, denneroll cervical traction improved cervical alignment and the improvement was maintained until one year follow-up(55). Further study is necessary to validate.

Comment 9: Paragraph Lines 375-380 - Limitations should be placed at end of discussion prior to conclusion.

Reply 9: We made a Limitations section before Conclusions section. (Page 14, line 17-20)

Change in the text: Limitations section is added before Conclusions section.

Comment 10: "Because of its complexity, comprehensive review will help for the purpose." Please reword, this is an awkward sentence.

Reply 10: The sentence is corrected as following. (Page 2, line 6-7)

Change in the text: Comprehensive review will help clinicians improve the management for patients with cervical deformity.

Comment 11: "We aimed to provide the state..." change to "We aimed to provide a state..."

Reply 11: We corrected as suggested. (Page 3, line 9-10)

Change in the text: We corrected as suggested.

Comment 12: remove comma after 'other'; change to 'Other iatrogenic causes...'

Reply 12: We corrected as suggested. (Page 5, line 11)

Change in the text: We corrected as suggested.

Comment 13: Line 156 - This is first mention of SVA - it needs to be spelled out with SVA in brackets. Also, where it is spelled out later (line 161-162 needs to be only written as SVA).

Reply 13: We corrected as suggested. (Page 7, line 6)

Change in the text: We corrected as suggested.

Comment 14: Line 181 - remove 'and' at end of sentence.

Reply 14: We corrected as suggested. (Page 8, line 23)

Change in the text: We corrected as suggested.

Comment 15: Line 378 - 'discretion at certain extent' should be changed to 'discretion in many instances.'

Reply 15: We corrected as suggested. (Page 14, line 27-28)

Change in the text: We corrected as suggested.

Comment 16: Line 380 - change 'ne' to 'be'

Reply: We corrected as suggested. (Page 15, line 20)

Change in the text: We corrected as suggested.