Cervicothoracic Lordosis Can Influence Outcome After Posterior Cervical Spine Surgery

Albert Vincent Berthier Brasil*, Pablo Ramon Fruett da Costa, Antonio Delacy Martini Vial, Gabriel da Costa Barcellos, Eduardo Balverdu Zauk, Paulo Valdeci Worm, Marcelo Paglioli Ferreira and Nelson Pires Ferreira

Department of Neurosurgery, Hospital São José – Santa Casa de Misericórdia de Porto Alegre, Porto Alegre, Rio Grande do Sul, Brazil

Received: December 13, 2017 Revised: February 02, 2018 Accepted: February 02, 2018

Abstract:

Background:

Previous studies on the correlation between cervical sagittal balance with improvement in quality of life showed significant results only for parameters of the anterior translation of the cervical spine (such as C2-C7 SVA).

Objective:

We test whether a new parameter, cervicothoracic lordosis, can predict clinical success in this type of surgery.

Methods:

The focused group involved patients who underwent surgical treatment of cervical degenerative disk disease by the posterior approach, due to myelopathy, radiculopathy or a combination of both. Neurologic deficit was measured before and after surgery with the Nurick Scale, postoperative quality of life, physical and mental components of SF-36 and NDI. Cervicothoracic lordosis and various sagittal balance parameters were also measured. Cervicothoracic lordosis was defined as the angle between: a) the line between the centroid of C2 and the centroid of C7; b) the line between the centroid of C7 and the centroid of T6. Correlations between postoperative quality of life and sagittal parameters were calculated.

Results:

Twenty-nine patients between 27 and 78 years old were evaluated. Surgery types were simple decompression (laminectomy or laminoforaminotomy) (3 patients), laminoplasty (4 patients) and laminectomy with fusion in 22 patients. Significant correlations were found for C2-C7 SVA and cervicothoracic lordosis. C2-C7 SVA correlated negatively with MCS (r=-0.445, p=0.026) and PCS (r=-0.405, p=0.045). Cervicothoracic lordosis correlated positively with MCS (r=0.554, p=0.004) and PCS (r=0.462, p=0.020) and negatively with NDI (r=-0.416, p=0.031).

Conclusion:

The parameter cervicothoracic lordosis correlates with improvement of quality life after surgery for cervical degenerative disk disease by the posterior approach.

Keywords: Cervicothoracic Lordosis, C2-C7 SVA, HRQOL, Posterior Approach, Cervical sagittal balance, Quality of life.

* Address correspondence to this author at the Department of Neurosurgery, Hospital São José – Santa Casa de Misericórdia de Porto Alegre, Rua Annes Dias, 295, Centro Histórico, CEP 90020-090, Porto Alegre, RS, Brazil; Tel: +55-51-81289946; Email: albertvb@terra.com.br
1. INTRODUCTION

The neurological improvement which is usually observed after cervical spinal cord decompression in cervical spondylotic myelopathy (CSM), may be accompanied by a lack of correspondent improvement in the quality of life [1], mostly due to continuing pain and its associated dysfunctions. While pain measurement scales are not usually good tools to capture and quantify these phenomena [2], the evaluation with some Health-Related Quality of Life (HRQOL) tests such as SF-36 and Neck Disability Index (NDI) demonstrated very clearly the dissociation between a consistent neurological improvement and a relatively unpredictable outcome in terms of dysfunction (NDI) or physical and mental quality of life - Mental Component Summary (MCS) and Physical Component Summary (PCS) of SF-36 [1, 3]. The tremendous progress recently achieved in the understanding of spinopelvic balance –and the associated muscle energy expenditure to maintain posture– was able to improve the surgical planning process in this area and to offer correspondingly improved clinical results [4]. This progress led to a renewed interest on the study of cervical sagittal balance, aiming to offer the same benefits for cervical spine patients. Unfortunately, the advancement in the knowledge about the cervical balance lags behind its thoracolumbar counterpart in a persistently slow pace [2, 3].

Cervical degenerative disc disease (DDD) can be operatively treated by the anterior and the posterior routes. The intuitive, simple and biomechanically plausible concept that cervical lordosis represents a fundamental surgical goal in posterior cervical surgery seems to be the first casualty in this recent surge of interest about cervical spinal balance. Some clinical series demonstrated that the intrinsic cervical lordosis may bear no correspondence with HRQOL after surgery, especially when performed by posterior approach [1, 2, 5 - 7]. Even more surprising was the report that cervical kyphosis was present and unnoticed in one third of asymptomatic persons [4].

We hypothesized that such a biologically plausible and intuitive concept as the clinical importance of cervical lordosis should not be simply abandoned. Our idea comes from the lumbar area, where lumbar lordosis cannot be considered as an independent surgical goal. The importance of lumbar lordosis can only be considered if one takes into consideration its mechanical and muscular relationships with the supporting pelvic structures [8]. The cervical spine is mainly supported by the upper half of the thoracic spine and by muscles that attach to the latter. One can then hypothesize that the reciprocal relationships between these two segments of the spine might be the determinant of the effectiveness of muscle efforts to maintain posture.

We retrospectively evaluated the data of patients operated in our service in order to verify if a new, simple and intuitive cervical sagittal parameter, which was called cervicothoracic lordosis (CTL) could correlate with the quality of life after the surgical treatment of cervical DDD performed by the posterior approach and help define the surgical strategy.

2. MATERIALS AND METHODS

The study was approved by the Ethics Committee of the Santa Casa de Misericordia Hospital Complex and the patients signed an Informed Consent Term (Termo de Consentimento Livre e Esclarecido) authorizing the procedure and the inclusion in the study protocol. Patients from both sexes, without any restriction of age, who were surgically treated in our service between March/2012 and July/2015 of cervical degenerative disk disease by the posterior approach were included. The reasons for the surgeries were myelopathy, radiculopathy or a combination of both problems. As primary outcome, this study has evaluated the effect of cervical sagittal balance on the quality of life of the patients. Secondary outcome measures were the correlation between the new parameter with other sagittal balance measures.

The analysis of postoperative cervical sagittal balance was performed with standing digital x-Rays of the whole spine, including the upper part of the femoral bones inferiorty up to the skull base superiorly. Measurements of angles and distances were performed with the software Surgimap V 2.2.9.6 by a trained physician who was not a part of surgical team and blindly revised by a spine surgeon expert. The following parameters were analyzed: C2-C7 SVA (sagittal vertical axis), Cobb C2-C7, and the new parameter proposed here, Cervicothoracic Lordosis (CTL). Cervicothoracic lordosis was defined as the angle between two lines: a) the line between the centroid of C2 and the centroid of C7; b) the line between the centroid of C7 and the centroid of T6 (Fig. 1). This angle was considered positive when it was positioned in lordosis and negative when in kyphosis. Millimeters and degrees were rounded to the unit.
Running Title: Cervicothoracic Lordosis Impacts Spine Surgery Outcomes The Open Orthopaedics Journal, 2018, Volume 12

3. RESULTS

There was a small but significant improvement in Nurick grade after surgery from 1.43±1.34 to 1.00±1.22 (p=0.05). NDI, PCS and MCS were measured preoperatively (NDI: mean 3.19±1.25; PCS - median 23.84 min=10, max=58; MCS: mean 46.9±14.609) and in the last evaluation (NDI: mean 2.81±1.10, MCS: mean 46.90±14.60, and PCS [nonparametric distribution] varied between 10 and 58 with a median value of 23.84). The postoperative improvement in PCS and MCS was statistically significant but the improvement in NDI was not. Improvement in PCS was significant (>5 points) in twelve patients (57%) and minimally clinically significant (>2.6 and <5) in one (5%). No improvement (<2.6 points) was detected in eight patients (38%). Significant improvement in MCS was observed in eleven patients (52%), minimally clinically significant improvement was detected in one patient (5%) and no improvement in 9 (43%). In 6 patients (25%) NDI improved significantly (more than 8.4 points), while in seven (29%), the improvement was minimally clinically significant (>3 and < 8.4). Eleven patients (46%) had no improvement in NDI [15].

The values of C2-C7 SVA, Cobb C2-C7 and CTL are presented in Table (1). Correlations between radiographic parameters and HRQOL measurements are shown in Table (2). Significant correlations were found exclusively for C2-C7 SVA and CTL. No correlation between Cobb C2-C7 and HRQOL measurements was detected.

4. DISCUSSION

Many parameters have been used to describe and study the cervical sagittal balance [3, 4, 16]. Attempts to correlate these parameters with clinical success after surgery were published by a few authors but most of the parameters showed no correlation with clinical data. Parameters that measure the anterior translation of the cervical spine like C2-C7 SVA stand almost alone as the only indicators for good outcome after surgery [1, 2]. The present findings demonstrate that the new parameter, CTL, correlates positively with HRQOL after surgery for cervical DDD by the posterior approach. Findings were significant for the Physical and the Mental Component Scores of the SF-36 as well as for NDI. In our
series, C2-C7 SVA showed the same type of correlation for PCS and MCS of SF-36 but not for NDI. All other parameters examined, including cervical lordosis, showed no correlation with quality of life Table (2). Our findings are in accordance with previous authors who found a similar correlation for C2-C7 SVA but not for all other parameters [1, 2]. We did not find any mention to cervicothoracic lordosis in previous literature.

Table 1. Details of the Patients.

| Gender      |  |    |    |
|-------------|---|----|----|
| Male        | 19|    |    |
| Female      | 10|    |    |
| Age         | Range Mean SD | 27-78 54.59 2.249|
| Disease     | Frequency Percent | Myelopathy 16 55% |
| Radiculopathy | 5 17% | Myelopathy + Radiculopathy 8 28% |
| Types of Surgery | Frequency Percent | Simple decompression 3 10.3% |
| Decompression with fusion | 22 75.9% |
| Operated levels | Levels Frequency Percent | 1 3 10.3% |
| | | 3 7 24.1% |
| | | 4 11 37.9% |
| | | 5 4 13.8% |
| | | 6 3 10.3% |
| | | 9 1 3.4% |

Post-operative Sagittal Alignment Measures  

| Measure                          | n | Minimum | Maximum | Results (M ± SD) |
|----------------------------------|---|---------|---------|-----------------|
| Cervicothoracic lordosis*        | 29| -35     | 20      | 4 (1 - 6)       |
| C2-C7 SVA                        | 29| 2       | 69      | 29.52 ± 14.60   |
| Cobb C2-C7                       | 29| -29     | 39      | 4.07 ± 14.26    |
| Cervicothoracic lordosis*        | 29| -35     | 20      | 4 (1 - 6)       |

M: mean; SD: standard deviation.  

Table 2. Correlation between HRQOL and Sagittal measures.

| Measure          | PCS* | MCS* | NDI | C2-C7 SVA | CTL | Cobb C2-C7 |
|------------------|------|------|-----|-----------|-----|------------|
| PCS*             | 1    | 0.66**| 1   |           |     | 1          |
| MCS*             | -0.82**| -0.67**| 1   |           |     | 1          |
| NDI              | -0.40*| -0.44*| 0.20|           | 1   |            |
| C2-C7 SVA        | 0.46*| 0.55**| -0.42*| -0.55** | 0.60**| 1          |
| Cobb C2-C7       | 0.11| 0.01 | -0.12| -0.53** | 0.60**| 1          |

* Post operatory values; * p < 0.05; ** P < 0.01. HRQOL (Health Related Quality of Life), PCS (Physical component summary of SF-36), MCS (Mental component summary of SF-36), NDI (Neck Disability Index), CTL (Cervicothoracic lordosis).

The concept of cervicothoracic lordosis proposed here was designed after a careful analysis of the previous data from the literature. Samundrala [17] and Deviren [18] described the correction of cervicothoracic deformity in cases that included post laminectomy and degenerative kyphosis. These authors performed PSO at C7 or T1 aiming to improve cervicothoracic lordosis (although they did not explicitly say so). The correction of this angle was accompanied by significant improvement in NDI and in the Physical and Mental components of SF-36. In fact, a careful review of the clinical cases presented the literature devoted to “postoperative cervical kyphosis” shows many patients who presented a decrease in cervicothoracic lordosis and not of intrinsic cervical lordosis [19 - 21].

Other authors tried to improve the understanding of cervical sagittal balance by including its relationships with neighboring thoracic or cranial structures. An attempt to replicate the model of Pelvic Index and its associated variables for the cervical spine was published by Lee et al [16]. This model is based on the assumption that Thoracic Inlet Angle
(TIA) is an anatomical constant, in the same fashion that the pelvic index. No study correlating these variables with HRQOL was published so far. The idea that TIA is a constant was threatened by Janusz et al. [22] who demonstrated that it can vary with the patient’s position. Le Huec [4] tried to expand the knowledge in this field with the study of many cranio cervical angles of normal asymptomatic persons. The analysis of 106 subjects led to the conclusion that the craniospinal angle should be in the range of 83±9 degrees in order to maintain normal energy expenditure in cervical muscles. It is interesting to note that this attempt to study reciprocal relations between the cervical spine and the cranium leads to a conclusion linking the cervical spine to the upper thoracic spine. In the same fashion that cervicothoracic lordosis, craniospinal angle represents the angle between the cervical spine axis and the inferior endplate of C7 which is an indirect representative of the axis of the upper thoracic spine or thoracic kyphosis.

The mechanics of C2-C7 SVA and CTL are simple. To understand the phenomena described here, one has to consider a mechanical system composed of one heavy object to be maintained in position (the head), one passive lever arm (the cervical spine as a whole), one active component (the erector spinae muscles), one supporting point for the lever arm (the superior endplate of T1) and the attachments of the muscles at the cervical spine at one end and at the superior half of the thoracic spine at the other end. As C2-C7 SVA increases, the moment of force applied by the weight of the head on the cervicothoracic junction increases proportionally Fig. (2). As cervicothoracic lordosis increases, the force vector applied by the muscles becomes progressively more perpendicular to the passive lever arm (more efficient) Fig. (3). In simple terms, C2-C7 SVA seems to measure the “weight of the head on the cervicothoracic junction”, while cervicothoracic lordosis represents how efficiently muscles apply the force necessary to support this weight.

![Fig. (2)](image1.png)

**Fig. (2).** Changes in the moment of force exerted by the head’s weight on the upper extremity of the thoracic spine vary according to C2-C7 SVA. A) Small C2-C7 SVA = small moment. B) large C2-C7 SVA = large moment.

![Fig. (3)](image2.png)

**Fig. (3).** C2-C7 SVA is the same in A' B' and C'. A and A': when CTL it is close to zero, the contraction of the spinae erector muscles generates a vector (F) too small in the extension of cervical spine. B and B', C and C': As Cervicothoracic lordosis magnifies, the resultant vector in the extension of the cervical column magnifies proportionally (F' e F'“) improving the effectiveness of the muscular contraction and diminishing the muscular energy expense.
The parameter “cervicothoracic lordosis” correlates with HRQOL after surgery for cervical degenerative disk disease by the posterior approach.

**LIST OF ABBREVIATIONS**

- **C2-C7 SVA** = C2-C7 Sagittal Vertical Axis
- **Cobb C2-C7** = C2-C7 Cobb Angles
- **CSM** = Cervical Spondylotic Myelopathy
- **CTL** = Cervicothoracic Lordosis (CTL)
- **HRQOL** = Health-Related Quality of Life
- **MCS** = Mental Component Summary of SF-36
- **NDI** = Neck Disability Index (NDI)
- **PCS** = Physical Component Summary (PCS) of SF-36
- **SF-36** = Short-Form-36
- **TIA** = Thoracic Inlet Angle (TIA)

**ETHICS APPROVAL AND CONSENT TO PARTICIPATE**

This study was approved by the Ethics Committee of the Santa Casa de Misericordia Hospital Complex and the patients signed an Informed Consent Term authorizing the procedure and the inclusion in the study protocol. (CAAE: 01957912.0.0000.5335)
HUMAN AND ANIMAL RIGHTS

All procedures were performed in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and the Helsinki Declaration of 1964 and later versions.

CONSENT FOR PUBLICATION

Written informed consent was obtained from all participants.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

ACKNOWLEDGEMENTS

We would like to thank the members of our surgical team, Dr Gabriel da Costa Barcellos, Dr Eduardo Balverdu Zauk and Dr Marcelo Neutzling Schuster, and also our research assistant, Claudia Sabrina Barroso, for their collaboration.

REFERENCES

[1] Roguski M, Benzel EC, Curran JN, et al. Postoperative cervical sagittal imbalance negatively affects outcomes after surgery for cervical spondylotic myelopathy. Spine 2014; 39(25): 2070-7. [http://dx.doi.org/10.1097/BRS.0000000000000641] [PMID: 25419682]

[2] Tang JA, Scheer JK, Smith JS, et al. The impact of standing regional cervical sagittal alignment on outcomes in posterior cervical fusion surgery. Neurosurgery 2012; 71(3): 662-9. [http://dx.doi.org/10.1227/NEU.0b013e31826100c9]. [PMID: 22653395]

[3] Scheer JK, Tang JA, Smith JS, et al. Cervical spine alignment, sagittal deformity, and clinical implications: a review. J Neurosurg Spine 2013; 19(2): 141-59. [http://dx.doi.org/10.3171/2013.4.SPINE12838]. [PMID: 23768023]

[4] Le Huec JC, Demezon H, Aunoble S. Sagittal parameters of global cervical balance using EOS imaging: normative values from a prospective cohort of asymptomatic volunteers. Eur Spine J 2015; 24(1): 63-71. [http://dx.doi.org/10.1007/s00586-014-3632-0]. [PMID: 25344642]

[5] Guérin P, Obeid I, Gille O, et al. Sagittal alignment after single cervical disc arthroplasty. J Spinal Disord Tech 2012; 25(1): 10-6. [http://dx.doi.org/10.1097/BSD.0b013e31820f16c] [PMID: 22124426]

[6] Jagannathan J, Shaffrey CI, Oskouian RJ, et al. Radiographic and clinical outcomes following single-level anterior cervical discectomy and allograft fusion without plate placement or cervical collar. J Neurosurg Spine 2008; 8(5): 420-8. [http://dx.doi.org/10.3171/SPI/2008/8/5/420] [PMID: 18447687]

[7] Villavicencio AT, Babuska JM, Ashton A, et al. Prospective, randomized, double-blind clinical study evaluating the correlation of clinical outcomes and cervical sagittal alignment. Neurosurgery 2011; 68(5): 1309-16. [http://dx.doi.org/10.1227/NEU.0b013e31820851f3]. [PMID: 21792113]

[8] Barrey C, Roussouly P, Perrin G, Le Huec JC. Sagittal balance disorders in severe degenerative spine. Can we identify the compensatory mechanisms? Eur Spine J 2011; 20(Suppl. 5): 626-33. [http://dx.doi.org/10.1007/s00586-011-1930-3] [PMID: 21796393]

[9] Nurick S. The pathogenesis of the spinal cord disorder associated with cervical spondylosis. Brain 1972; 95(1): 87-100. [http://dx.doi.org/10.1093/brain/95.1.87] [PMID: 5023093]

[10] Ware JE Jr, Sherbourne CD. The MOS 36-item short-form health survey (SF-36). I. Conceptual framework and item selection. Med Care 1992; 30(6): 473-83. [PMID: 1593914]. [http://dx.doi.org/10.1097/00005650-199206000-00002] [PMID: 1593914]

[11] Vernon H, Mior S. The Neck Disability Index: a study of reliability and validity. J Manipulative Physiol Ther 1991; 14(7): 409-15. [PMID: 1834753]

[12] McHorney CA, Ware JE Jr, Glassman SD, Polly DW Jr, Schuler TC. Understanding the minimum clinically important difference: a review of concepts and methods. Spine J 2007; 7(5): 541-6. [http://dx.doi.org/10.1016/j.spinee.2007.01.008]. [PMID: 17448732]
[14] Copay AG, Glassman SD, Subach BR, Berven S, Schuler TC, Carreon LY. Minimum clinically important difference in lumbar spine surgery patients: a choice of methods using the Oswestry Disability Index, Medical Outcomes Study questionnaire Short Form 36, and pain scales. Spine J 2008; 8(6): 968-74. [http://dx.doi.org/10.1016/j.spinee.2007.11.006]. [PMID: 18201937]

[15] Pool JJ, Ostelo RW, Hoving JL, Bouter LM, de Vet HC. Minimal clinically important change of the Neck Disability Index and the Numerical Rating Scale for patients with neck pain. Spine 2007; 32(26): 3047-51. [http://dx.doi.org/10.1097/BRS.0b013e31815e75b] [PMID: 18091500]

[16] Lee S-H, Kim K-T, Seo E-M, Suk K-S, Kwack Y-H, Son E-S. The influence of thoracic inlet alignment on the craniocervical sagittal balance in asymptomatic adults. J Spinal Disord Tech 2012; 25(2): E41-7. [http://dx.doi.org/10.1097/BSD.0b013e3182393630] [PMID: 22037167]

[17] Samudrala S, Vaynman S, Thiayananthan T, et al. Cervicothoracic junction kyphosis: surgical reconstruction with pedicle subtraction osteotomy and Smith-Petersen osteotomy. Presented at the 2009 Joint Spine Section Meeting. Clinical article. J Neurosurg Spine 2010; 13(6): 695-706. [http://dx.doi.org/10.3171/2010.5.SPINE08608]. [PMID: 21121746]

[18] Deviren V, Scheer JK, Ames CP. Technique of cervicothoracic junction pedicle subtraction osteotomy for cervical sagittal imbalance: report of 11 cases. J Neurosurg Spine 2011; 15(2): 174-81. [http://dx.doi.org/10.3171/2011.3.SPINE10536] [PMID: 21529128]

[19] Grosso MJ, Hwang R, Krishnaney AA, Mroz TE, Benzel EC, Steinmetz MP. Complications and Outcomes for Surgical Approaches to Cervical Kyphosis. J Spinal Disord Tech 2015; 28(7): E385-93. [http://dx.doi.org/10.1097/BSD.0b013e3182999533] [PMID: 23732179]

[20] Han K, Lu C, Li J, et al. Surgical treatment of cervical kyphosis. Eur Spine J 2011; 20(4): 523-36. [http://dx.doi.org/10.1007/s00586-010-1602-8]. [PMID: 20967471]

[21] Oghara S, Kunogi J. Single-stage anterior and posterior fusion surgery for correction of cervical kyphotic deformity using intervertebral cages and cervical lateral mass screws: Postoperative changes in total spine sagittal alignment in three cases with a minimum follow-up of five years. Neurol Med Chir (Tokyo) 2015; 55(7): 599-604. [http://dx.doi.org/10.2176/nmc.cr.2014-0263]. [PMID: PMC4628194]. [PMID: 26119893]

[22] Janusz P, Tyrakowski M, Glowka P, Offoha R, Siemionow K. Influence of cervical spine position on the radiographic parameters of the thoracic inlet alignment. Eur Spine J 2015; 24(12): 2880-4. [http://dx.doi.org/10.1007/s00586-015-4023-x]. [PMID: 25987456]

[23] Epstein NE. What you need to know about ossification of the posterior longitudinal ligament to optimize cervical spine surgery: A review. Surg Neurol Int 2014; 5(Suppl. 3): S93-S118. [http://dx.doi.org/10.4103/2152-7806.130696]. [PMID: PMC4023010]. [PMID: 24843819]

[24] McAllister BD, Rebholz BJ, Wang JC. Is posterior fusion necessary with laminectomy in the cervical spine? Surg Neurol Int 2012; 3(Suppl. 3): S225-31. [http://dx.doi.org/10.4103/2152-7806.98581]. [PMID: PMC3422093]. [PMID: 22905328]

[25] Singh K, Hoskins JA, Yelavarthi V, Vaccaro AR. Cervical spine: Lateral mass screw fixation. Spine Surgery. 2nd ed. Philadelphia: Elsevier-Saunders 2012; pp. 101-7.

[26] Hardacker JW, Shuford RF, Capicotto PN, Pryor PW. Radiographic standing cervical segmental alignment in adult volunteers without neck symptoms. Spine 1997; 22(13): 1472-80. [http://dx.doi.org/10.1097/00007632-199707010-00009] [PMID: 9231966]

[27] Jackson RP, McManus AC. Radiographic analysis of sagittal plane alignment and balance in standing volunteers and patients with low back pain matched for age, sex, and size. A prospective controlled clinical study. Spine 1994; 19(14): 1611-8. [http://dx.doi.org/10.1097/00007632-199407001-00010] [PMID: 7939998]