A novel method for measurement of occipital-cervical distance by occiput-C4 distance

CURRENT STATUS: POSTED

Chao Tang
Affiliated Hospital of Southwest Medical University
ORCiD: https://orcid.org/0000-0002-9352-6567

Sheng Yang
Affiliated hospital of southwest medical university

Ye Hui Liao
Affiliated hospital of southwest medical university

Qiang Tang
Affiliated hospital of southwest medical university

Fei Ma
Affiliated hospital of southwest medical university

Qing Wang
Affiliated hospital of southwest medical university

Dejun Zhong
zdj_1974@163.com Corresponding Author
ORCiD: https://orcid.org/0000-0002-3208-2173

DOI:
10.21203/rs.2.15905/v1

SUBJECT AREAS
Orthopedics

KEYWORDS
occiput-cervical distance, C4 vertebral body, McGregor’s line
Abstract

**Background:** To describe and measure the occipital-cervical distance by a novel method utilizing the occiput-C4 distance (OC4D) in normal subjects that can be used to guide the restoration of vertical dislocation of the occipitocervical region in patients with basilar invagination and to perform standardized testing of occipitocervical constructs.

**Methods:** Neutral, flexion, and extension lateral cervical spine radiographs of 150 asymptomatic subjects (73 males and 77 females) judged to be normal were analyzed. The mean age was 48.0±8.4 years old (range 20–69 years; 48.4±10.2 years old for males and 47.6±6.4 years old for females). Analysis consisted of measurement of the OC4D. The OC4D was defined as the shortest distance from the center of the C4 vertebral body to the McGregor’s line. Two spine surgeons measured the OC4D thrice in the normal population and obtained the average values. Height, weight, and body mass index (BMI) of each subject was recorded and analyze its correlation with OC4D.

**Results:** The values of OC4D on neutral, flexion, and extension lateral cervical spine radiographs were 69.0±6.9 mm, 68.9±6.8 mm and 68.1±6.9 mm, respectively. There was no significantly different from the values measured in neutral-flexion and extension (P > 0.05). But the OC4D of males were higher than females in neutral, flexion, and extension (P < 0.001 for all). There was a positive correlation between OC4D and height and weight in neutral-flexion and extension (P <0.001 for all). The correlation between O-C4D and BMI was weak, and no significant in neutral, flexion, and extension (P > 0.05). The ICC values of inter- and intra-observer agreements for the radiographic parameter in all of the cervical positions were more than 0.93.

**Conclusions:** OC4D, a new measurement method for occipital-cervical distance that is not affected by the change in neutral, flexion, and extension positions, should be a valuable parameter and intra-operative tool to guide the vertical restoration during OCF for patients with altered occiput-cervical anatomy.

**Background**
Craniocervical joint instability caused by a congenital anomaly (e.g., basilar invagination), trauma, inflammatory disease, and a tumor may be an indication for occipitocervical fusion (OCF) [1]. During
occipitocervical fixation and fusion, the ability to confirm that the occiput is in a neutral balance position in relation to the cervical spine is a very important skill. Current literature tends to focus on the effect of occipitocervical angle fixation on postoperative dyspnea/dysphagia and lower cervical spine degeneration [2,3]. However, few researchers have focused on the relationship between the distance of occipital-cervical vertical reduction and lower cranial nerve palsy following vertical over-distraction. Therefore, we consider that a normal occiput-cervical distance is very important for avoiding over-distraction injury to the cranial nerve/spinal cord during OCF. Previously, the occiput-cervical distance was obtained by measuring the shortest distance from the most superior aspect of the C2 spinous process to the occipital protuberance [4]; however, this measurement method is significantly affected by even minimal head rotation. The C4 vertebral body, with a landmark at the mid-cervical level, is less affected by upper cervical spine motion, which makes it easy to define the occipitocervical neutral position during fusion surgery [5].

In this study, we introduced the occiput-C4 distance (OC4D) measurement method, which makes it simple and practical to perform the evaluation. At the same time, we measured and compared the OC4D in different cervical positions and obtained normal value ranges, and further analysis of the correlation between weight, height, body mass index (BMI) and OC4D, which will help to define the occipitocervical neutral position more comprehensively and accurately. This study will provide a practical measurement method and its reference values for the definition of occiput-cervical vertical reduction during OCF.

Methods
In this study, we included 150 lateral cervical spine radiographs, which were interpreted by two spine surgeons as normal (i.e., absence of fracture or dislocation, absence of deformity, absence of severe osteophyte formation, absence of destruction of the vertebrae, and absence of spondylosis), from a radiographic database at Affiliated Hospital of Southwest Medical University, China. The study population consisted of 75 males and 75 females with an average age of 48.0 years (range 20–69 years; 48.4 years for male subjects and 47.6 years for female subjects). The X-ray tube was centered at C4, and the radiographs were taken from a distance of 2 m from the subject’s left side. Approval
for this study was obtained from the Ethics Committee of the Affiliated Hospital of Southwest Medical University, China.

Analysis of lateral neutral, flexion, and extension radiographs was performed using the new measurement method, occiput-C4 distance (OC4D). The OC4D was defined as the shortest distance from the center of the C4 vertebral body to the McGregor’s line (Fig. 1). Two spine surgeons calculated and documented the OC4D on all of the radiographs in a blinded manner. The parameter was measured by both observers on three occasions with an interval of at least 2 weeks, and the average value was used for comparisons.

Body height, weight, and BMI of each subject was recorded by co-authors in this study, and BMI formula was calculated as follows:

\[ \text{BMI} = \frac{\text{Weight (Kg)}}{\text{Height (m)}^2} \]

Statistical Analysis

SPSS software version 19.0 (SPSS Inc, Chicago, IL, USA) was used for all of the statistical analyses. A difference analysis of OC4D in each cervical position was performed between male and female subjects using Student’s \( t \) test. Pearson’s coefficient was used to analyze correlations between OC4D and height, weight, and BMI. Inter- and intra-observer reliabilities were assessed by calculating intraclass and interclass correlation coefficients (ICCs). Data are expressed as mean ± standard deviation of the mean, and they were considered statistically significant at \( P < 0.05 \).

Results

The mean value of OC4D in the neutral position was 69.0±6.9 mm, and it was not significantly different from the values measured in flexion (68.9±6.8 mm) and extension (68.1±6.9 mm) (\( P > 0.05 \)) (Table 1).

The values of OC4D in neutral, flexion, and extension cervical positions were analyzed between male and female subjects, and they are summarized in Table 2. The OC4D of males were higher than females in neutral, flexion, and extension (\( P < 0.001 \) for all). However, there was no significantly different from the values between neutral, flexion or extension positions in males or females (\( P > 0.05 \) for all).
Correlations of OC4D with height, weight, and BMI were evaluated in the whole study subjects. There was no significant association between OC4D and BMI in the whole study subjects (P > 0.05) (Table 5). However, OC4D is strongly positive correlation with height (r = 0.707 in neutral, r = 0.707 in flexion, and r = 0.666 in extension, P < 0.001 for all) (Table 3). The correlation between OC4D and weight was moderate, but significant in neutral, flexion, and extension (neutral: r = 0.541, flexion: r = 0.541, and extension: r = 0.505, P < 0.001 for all) (Table 4).

The ICC values of inter-observer agreement for OC4D were 0.945, 0.953, and 0.961 in neutral, flexion, and extension positions, respectively; and the ICC values of intra-observer agreement for OC4D were 0.932, 0.962, and 0.958 in neutral, flexion, and extension positions, respectively.

Discussion

In this study, we determined the reference values for estimating the occipital-cervical distance in neutral, flexion, and extension positions by OC4D, a new radiographic parameter measurement method. The measurement method should provide a comprehensive and accurate estimation for vertical reduction of the occiput-cervical region while performing OCF. OC4D, a simple, convenient, and highly reliable measurement method for occiput-cervical distance, is not occluded by implants. More importantly, it is not affected by the change in head and neck position.

Conceptually, the occipitocervical neutral position is the functional and balanced position of the head on the cervical spine. We considered that patients should have a normal occipitocervical angle and occiput-cervical distance in this position. Sherekar et al [6] measured the occipito-C2 angle in 518 asymptomatic volunteers (261 male and 257 female subjects), and they obtained values of 14.66 ± 9.5° in males and 15.59 ± 8.26° in females. Many researchers reported that non-normal occipitocervical angles led to poor postoperative fusion, even severe dysphagia and/or dyspnea during OCF [3, 7–9]. However, it is still unknown whether dysphagia and/or dyspnea mostly due to mechanical airway obstruction caused by a non-normal occipitocervical angle. We believe that surgeons should pay attention to the lower cranial nerve stretch airway obstruction caused by over-distraction of the occiput-cervical vertical distance. Shigeto E et al. reported that the mechanism of dysphagia is not simply associated with the O-C2 angle, but it also involves the global craniocervical
alignment in an individual patient, including the occiput-cervical distance [10]. Wang Q et al. reported that performing OCF in the over-distraction position to treat vertical atlantoaxial dislocation may caudally displace the brainstem relative to the cranial base, resulting in traction injury to the 9th, 10th, and 11th lower cranial nerves [11].

In 1999, Phillips et al. first measured the occiput-cervical distance (OCD) by measuring the shortest distance from the most superior aspect of the C2 spinous process to the occipital protuberance in 30 asymptomatic subjects. The value of OCD in the neutral position was 21.5±1.22 mm, and it was significantly different from the values measured in flexion (28.0±1.32 mm) and extension (14.8±1.48 mm) [4]. Seong et al. measured OCD in 200 normal, sagittal balanced patients (100 male and 100 female patients), and the mean neutral OCD was 22.98 ± 5.10 mm (range, 9.88–38.64 mm). Both these values were significantly different from those in flexion and extension positions [5]. Unfortunately, the correlation between OCD and height, weight and BMI had not been reported in previous literature. In our study, we measured the occiput-cervical distance by OC4D, and the mean neutral OC4D was 69.0±6.9 mm. However, this value was not significantly different from those measured in flexion (68.9±6.8 mm) and extension (68.1±6.9 mm). Seong et al. found that the posterior border of C4 as a landmark is the apex of cervical lordosis, and it is therefore the least affected by the cervical curve [5].

We hypothesized that the C4 vertebral body, being the central point of the cervical sequence, is the least affected by motion of the cervical position. Hence, the shortest distance from the center of the C4 vertebral body to the McGregor’s line in different cervical positions can be regarded as the radius of a circle, and the circle is positioned at the center of the C4 vertebral body and tangent to the McGregor’s line (Fig. 2). Meanwhile, we found a positive correlation between OC4D and height as well as weight in this study, and we observed that it had a stronger correlation between OC4D and height compared to weight. But the correlation between OC4D and BMI was weak, and it was no statistically significant.

O-C4D, compared with OCD in previously reported literature [4, 5, 12], has its own unique advantages. First of all, the OC4D is a more accurate parameter. In OCD, significant inter-individual
morphologic variation in the C2 spinous process and gender differences have been detected. Jiang wei T et al. found that variations in the C2 spinous process may affect the OCD value and there was a significant different between male and female subjects [12]. The inter- and intra-observer reliabilities of OCD had ICC values of 0.651 and 0.754 in Seong's study [5]. In this paper, we found that the posterior margin of the hard palate, occipital bone, and C4 vertebra, with less bone variation, were clear on lateral radiographs. The ICC values of inter- and intra-observer agreements for OC4D were more than 0.93 in neutral, flexion, and extension positions. Second, the OC4D, as an ingenious measurement method, is less affected by motion of the head and neck in neutral, flexion, or extension position. Obviously, the alignment of the subaxial spine can influence the occipitocervical alignment required to ensure a functional position of the occiput. This variable was not specifically measured in the current study. So far, only a few articles on the OCD measurements have been reported, and both of these articles showed that the mean neutral OCD value was significantly different from those in flexion and extension positions (Fig. 3) [4, 5, 9]. However, there was no significant difference in the OC4D measurement method among neutral, flexion, and extension positions. It has clinical significance for guiding reduction during the operation but the occiput-cervical region is not in a neutral position. Third, the O-C4D is not occluded by implants and it may be a valuable intraoperative tool for designing of fusion implants and testing of the restoration condition in the operating room. Although it is already known, there are no reports showing that the C2 spinous process can be occluded by fixed implants during OCF and the implants could affect the measurement by the OCD method (Fig. 4). Previous literature has stated that it may be difficult to visualize the tip of the dens on radiographs, or the dens may be absent or fixed in an abnormal position in many conditions for which OCF is performed [13, 14]. Therefore, it may be difficult and inaccurate to evaluate vertical reduction of the occipitocervical region by the distance from the odontoid tip to the McGregor’s line during surgery. Wang Q et al. first described lower cranial nerve palsy following vertical over-distraction after OCF in 4 patients who had atlantoaxial dislocation with or without basilar invagination, and the symptoms of all of the patients were alleviated to different extents by releasing the screw cap and recovery to partial reduction of the occipitoatlantal anatomy [11].
However, the OC4D method avoids the occlusion caused by implants and uncertainty of bony landmarks on radiographs, and it could be a useful tool to estimate and test the restoration condition of the occipitoatlantal anatomy by regulating the fixed implants.

The limitations of this study are as follows: the demographic data were not matched for age and the sample size was relatively small. In spite of these limitations, our study could present a new method for measurement of occipital-cervical distance, and it has practically valuable to guide and test the restoration condition of occipital-cervical region. Another limitation of this study is that only the cervical plain radiographs were analyzed, there was no data about the overall sagittal alignment of the spine in the study sample. Although previous literature has reported that cervical curvature could be affected by overall spinal sagittal imbalance [15–18], normal subjects with a normal cervical curvature were included in our study, and we found no difference between OC4D and the change of cervical curvature in neutral, flexion, and extension. However, we also recognized that cervical curvature changes can accelerate cervical degeneration, which maybe affect the results of OC4D measurements. Thus, prospective studies are needed to obtain more reliable measurements about cervical or overall spine sagittal alignment parameters, and further explore the effect of spinal sagittal parameters on OC4D.

Conclusion
In this study, we proposed and introduced a new measurement method for occipital-cervical distance by the shortest distance from the center of the C4 vertebral body to the McGregor’s line (OC4D). We found that there was no significantly different from the values of OC4D between neutral, flexion or extension positions in males or females, and there was a positive significant correlation between OC4D and height and body weight. OC4D, a new measurement method for occipital-cervical distance that is not affected by the change in neutral, flexion, and extension positions, should be a valuable parameter and intra-operative tool to guide the vertical restoration during OCF for patients with altered occiput-cervical anatomy.

Abbreviations
OC4D: Occiput-C4 distance; BMI: Body mass index; ICCs: Intraclass and interclass correlation
coefficients; OCF: Occipitocervical fusion; OCD: Occiput-cervical distance

Declarations
Ethical approval and consent to participate
The study protocol was approved by the Ethics Committee of the Affiliated Hospital of Southwest Medical University.

Authors’ contributions
All authors made substantial contributions to this article. TC and ZDJ conceived the original study and developed the protocol together with YS. TC and ZDJ conceived and designed the study. TC, YS, LYH and TQ participated in the study and gathered data. YS, LYH and WQ analyzed and interpreted the data. TC initially drafted the manuscript, ZDJ and WQ statistically analyzed and ensured the accuracy of the data, and TC, ZDJ and YS conducted the revision and editing of the manuscript. All authors have read and approved the final version of the manuscript and affirm that the work has not been submitted or published elsewhere in whole or in part.

Funding
No funds were received in support of this work.

Availability of data and materials
Data will be available upon request to the first author TC.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

Consent for publication
All participants provided their consent to publish their data and accompanying images.

Acknowledgements
Not applicable.

References
1. Grob D (2000) Posterior occipitocervical fusion in rheumatoid arthritis and other instabilities. J Orthop Sci 5:82–7

2. Masanori I, Masashi N, Mitsuru T, et al (2014) The O-C2 angle established at occipitocervical fusion dictates the patient’s destiny in terms of postoperative dyspnea
and/or dysphagia. Eur Spine J 23:328–36

3. Inada T, Furuya T, Kamiya K, et al (2016) Postoperative Increase in Occiput-C2 Angle Negatively Impacts Subaxial Lordosis after Occipito-Upper Cervical Posterior Fusion Surgery. Asian Spine J 10:744–747. DOI:10.4184/asj.2016.10.4.744

4. Phillips FM, Phillips CS, Wetzel FT (1999) Occipitocervical neutral position. Possible surgical implications. Spine (Phila Pa 1976) 24:775–778

5. Seong D, Chang H, Jiwoon L, et al (2017) Occipitocervical inclination: new radiographic parameter of neutral occipitocervical position. Eur Spine J 26: 2297–2302. DOI:10.1007/s00586-017-5161-0

6. Sherekar SK, Yadav YR, Basoor AS, et al (2006) Clinical implications of alignment of upper and lower cervical spine. Neurol India 54:264–267

7. Matsunaga S, Onishi T, Sakou T (2001) Significance of occipitoaxial angle in subaxial lesion after occipitocervical fusion. Spine 26:161–165

8. Logroscino CA, Genitiempo M (2009) Relevance of the cranioaxial angle in the occipitocervical stabilization using an original construct: a retrospective study on 50 patients. Eur Spine J 18 Suppl 1:7–12. DOI:10.1007/s00586-009-0985-x

9. Veena S, Rebecca M, Pirjo M, et al (2017) Airway adverse events following posterior occipito-cervical spinal fusion. J Clin Neurosci 39:124–129. DOI:10.1016/j.jocn.2016.12.036

10. Shigeto E, Kyousuke H, Tetsuro O, et al (2015) Swallowing function after occipitocervical arthrodesis for cervical deformity in patients with rheumatoid arthritis. Neuro Rehabilitation 37:299–304. DOI:10.3233/NRE-151262

11. Wang Q, Wu X, Tan M, et al (2018) Is Anatomic Reduction Better Than Partial Reduction in Patients with Vertical Atlantoaxial Dislocation? World Neurosurg 114:e301-e305. DOI:10.1016/j.wneu.2018.02.176
12. Tan J, Liao G (2014) Evaluation of occipitocervical neutral position using lateral radiographs. J Orthop Surg Res 9:87. DOI:10.1186/s13018-014-0087-2
13. Harris JH, Carson GC, Wagner LK (1994) Radiologic diagnosis of traumatic occipitovertebral dissociation: 2. Comparison of three methods of detecting occipitovertebral relationships on lateral radiographs of supine subjects. AJR Am J Roentgenol 162:887-892. DOI:10.2214/ajr.162.4.8141013
14. Uno K, Kataoka O (1996) Occipitoatlantal and occipitoaxial hypermobility in Down syndrome. Spine (Phila Pa 1976) 21:1430-1434
15. Knott PT, Mardjetko SM (2010) The use of the T1 sagittal angle in predicting overall sagittal balance of the spine. The spine journal: official journal of the North American Spine Society 10(11):994-998. DOI:10.1016/j.spinee.2010.08.031
16. Roussouly P, Pinheiro-Franco JL (2011) Sagittal parameters of the spine: biomechanical approach. Eur Spine J Off Publ Eur Spine Soc Eur Spinal Deform Soc Eur Sect Cerv Spine Res Soc 20(Suppl 5):578-585
17. Lin BJ, Hong KT, Lin C, et al (2018) Impact of global spine balance and cervical regional alignment on determination of postoperative cervical alignment after laminoplasty. Medicine (Baltimore) 97(45):1-7 DOI:10.1097/MD.0000000000001311
18. Le Huec JC, Thompson W, Mohsinaly Y, et al (2019) Sagittal balance of the spine. Eur Spine J. DOI:10.1007/s00586-019-06083-1

Tables
Due to technical limitations, all Table(s) are only available as a download in the supplemental files section.

Figures
Figure 1

The new measurement method of occipital-cervical distance by occiput-C4 distance (O-C4D) in neutral(A), flexion(B), and extension(C) positions. The O-C4D was defined as the shortest distance from the center of the C4 vertebral body to the McGregor’s line.
Figure 2

The vertebral body of C4, an apex most visible on radiographs and least affected by the cervical curve, was designated as a landmark. The O-C4D can be regarded as the radius of a circle, and the circle is positioned at the center of the C4 vertebral body and tangent to the McGregor’s line.
Measurement differences of occipital-cervical distance (OCD) due to cervical positions in neutral(A), flexion(B), and extension(C). OCD was defined as the shortest distance from the most superior aspect of the C2 spinous process to the occipital protuberance.
Figure 4

C2 spinous process and occipital protuberance can be occluded by fixed implants during occipital-cervical fusion (OCF) and the implants could affect the measurement by the occipital-cervical distance (OCD) method.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

Table 3.pdf
Table 4.pdf
Table 5.pdf
Table 2.pdf
Table 1.pdf