Clinical Study

McGregor's slope and slope of line of sight: two surrogate markers for Chin-Brow vertical angle in the setting of cervical spine pathology

Michael J. Moses, MD, Jared C. Tishelman, BA, Peter L. Zhou, BA,
John Y. Moon, BS, Bryan M. Beaubrun, BA,
Aaron J. Buckland, MBBS, FRACS, Themistocles S. Protopsaltis, MD*

Department of Orthopaedic Surgery, Division of Spine Surgery, New York University Langone Medical Center, Hospital for Joint Diseases, New York, NY 10003, USA

Abstract

BACKGROUND CONTEXT: Chin-Brow Vertical Angle (CBVA) is not routinely measured on radiographs even though it is a strong assessor of horizontal gaze.

STUDY DESIGN: Retrospective cohort study of patients with full-body stereoradiographs and a primary cervical diagnosis at the time of presentation.

PURPOSE: Assess the utility of McGregor's Slope (McGS) and Slope of Line of Sight (SLS) as surrogate markers for the CBVA in cervical spine pathology.

METHODS: A retrospective review of patients with full-body stereoradiographs was performed. Patients were ≥18 years of age with a primary cervical diagnosis. Analysis of CBVA, McGS, and SLS was conducted as markers of horizontal gaze. Sagittal alignment was characterized by: pelvic tilt (PT), pelvic incidence minus lumbar lordosis (PI-LL), T1-pelvic angle (TPA), sagittal vertical axis (SVA), T2-T12 thoracic kyphosis, C2-C7 SVA (cSVA), C2-C7 Cervical lordosis, T1-Slope minus Cervical Lordosis (TS-CL), and C2-Slope (C2S). A subgroup analysis was performed in patients with cervical deformity. Independent sample t tests and paired t tests compared radiographic alignment. Pearson correlations characterized linear relationships. Linear regression analysis identified relationships between the parameters.

RESULTS: In all, 329 patients were identified with primary cervical spine diagnoses. Chin-Brow Vertical Angle was visible in 171 patients (52.0%), McGS in 281 (85.4%), and SLS in 259 (78.7%). Of the 171 patients with visible CBVA, the mean CBVA was 2.30±7.7, mean McGS was 5.02±8.1, and mean SLS was −1.588±2.03. Chin-Brow Vertical Angle strongly correlated with McGS (r=0.83) and SLS (r=0.89) with p<.001. McGregor's Slope positively correlated with SLS (r=0.89, p=.001).

CONCLUSIONS: This study demonstrates that McGS and SLS serve as strong, positive correlates for CBVA. The reported mean differences between these measurements provide a useful conversion, broadening CBVA's use as a radiographic assessment of horizontal gaze.   © 2019 Published by Elsevier Inc.

Key words: Biomechanics; CBVA; Cervical; Deformity; McGregor's slope; SLS

* Corresponding author. Department of Orthopaedic Surgery, Hospital for Joint Diseases, New York University Langone Medical Center, 301 East 17th St, New York, NY 10003, USA. Tel.: 212.598.6509; fax: 212.598. 7654.

E-mail address: Themistocles.protopsaltis@nyumc.org (T.S. Protopsaltis).

Introduction

The cervical spine plays a critical role in the maintenance of horizontal gaze, which has been directly correlated to patient-reported quality of life [1,2,3]. When cervical deformity (CD) compromises horizontal gaze, patients may present with impaired swallowing and difficulty carrying out their daily activities [4]. Horizontal gaze has typically been assessed radiographically using the Chin-Brow Vertical Angle (CBVA), initially characterized by Simmons in the setting of patients with ankylosing spondylitis [5]. Surgical correction is often necessary to restore horizontal gaze and quality of life for patients [6].

Advancement of radiographic technology has led to full-body stereoradiographic imaging systems (EOS Imaging, SA, Paris, France), providing a wide field of visualization of the full skeletal axis, thus allowing for greater preoperative planning and measurement to be systemically obtained before surgical deformity correction [7]. Full-body EOS has been shown to be a viable alternative for measuring cervical alignment parameters, as compared with standard radiography [8]. There are limitations, however, to the full-body EOS as the landmarks for CBVA are not typically captured.

Radiographic assessment of craniocervical alignment before deformity correction includes the CBVA in addition to the Slope of Line of Sight (SLS) [9] and McGregor's Slope (McGS) [10−12]. To date, most of these measurements have been analyzed solely in the context of thoracolumbar deformity, and never in the context of cervical spine pathology [13,14]. These parameters can help in the assessment of occipitocervical alignment. These 3 parameters correlate strongly with each other and can be used as surrogate measures in a thoracolumbar deformity cohort [11]. The purpose of this study is to evaluate the anatomic relationships of CBVA, SLS, and McGS and their radiographic accessibility in cervical spine pathologies.

Methods

Study design

We conducted a retrospective review of a database of patients presenting for evaluation at an academic spine surgery practice with full-body standing stereoradiographs.

Participants

Inclusion criteria for the study were age ≥18 years and a primary cervical spinal pathology. Subgroup analysis was conducted to compare patients with radiographic evidence of CD to those presenting for other cervical spinal pathologies. Cervical deformity was defined as the presence of at least 1 of the following: cervical kyphosis (C2-7 sagittal Cobb angle >10° kyphosis), cervical scoliosis (C2-7 coronal Cobb angle <10°), C2-7 sagittal vertical axis (cSVA) >4 cm. Patients with active tumors or infections were excluded from the study. Institutional Review Board approval was obtained for the single center involved in this study. Informed consent was not required as this was a study conducted on a deidentified patient database.

Variables

Radiographic sagittal alignment was characterized by the following parameters: pelvic tilt (PT), pelvic incidence minus lumbar lordosis (PI-LL) mismatch, T1-pelvic angle (TPA), sagittal vertical axis (SVA), T2-T12 thoracic kyphosis, C2-C7 SVA (cSVA), C2-C7 cervical lordosis (CL), T1-Slope minus CL (TS-CL), and C2-Slope (C2S). All measurements were performed using dedicated and validated surgical planning software, Surgimap 2.2.7. (Nemaris Inc, New York, NY, USA) [15]. The occipitocervical alignment parameters, including the CBVA, which is defined as the angle formed by a vertical line and a line connecting the most anterior aspect of the forehead and chin [5], SLS, which is the angle made between the horizontal and the Frankfort plane (the upper pole of the external auditory canal to the lower pole of the orbit) [9], and McGS, the angle from the posterior aspect of the hard palate to the opisthion in relation to a horizontal line [10−12] were compared for visibility on full-length standing radiographs (Fig. 1). The horizontal gaze parameters were considered visible if the anatomical landmarks that form the component line of their angle were visible on the radiographs. The patient cohort was divided into 2 groups based on magnitude of McGS and compared for baseline alignment.
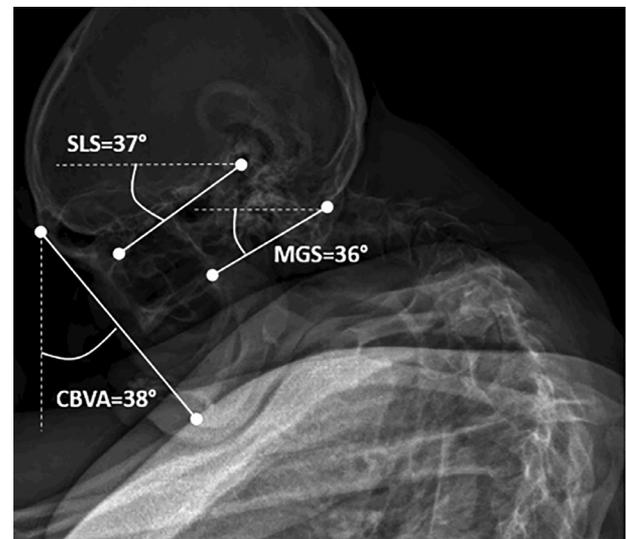

Fig. 1. A radiograph depicting the horizontal gaze parameters and proposed surrogates. Chin-Brow Vertical Angle (CBVA): the angle formed by a vertical line and a line connecting the most anterior aspect of the forehead and chin. The McGregor's Slope (MGS): Angle of the line from the posterior aspect of the hard palate to the opisthion in relation to a horizontal line. The Slope of Line of Sight (SLS): which is the slope of the Frankfort line from the anterior/inferior margin of the orbit to the top of the external auditory meatus.

Bias

We attempted to minimize selection bias by using a deidentified database. Additionally, we eliminated loss-to-follow-up bias by solely capturing a snapshot at the time of patient presentation.

Study size

The study size was arrived at by finding those patients that met the inclusion criteria of the study in our patient database.

Quantitative variables

The main quantitative variables used were the measurements obtained from our database regarding the different occipitocervical and spinal parameters in question. We separated our cohort into those patients with CD and those without, to evaluate for significant differences in measurement of these parameters or other demographic criteria between these 2 subgroups. Additionally, we further substratified the CD subgroup into those with large McGS and those with a small McGS to better appreciate any granularity between this subgroup.

Statistical methods

Independent sample *t* tests and paired *t* tests were used to compare radiographic alignment between cohorts with significance set at $p<.05$. Pearson correlations allowed for characterization of linear relationships between variables. Linear regression analysis was later performed to identify predictive relationships between the occipitocervical parameters. All statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS Version 23.0, IBM Corp., Armonk, NY, USA). The STROBE guideline was used in this study.

Results

Participants and descriptive data

A total of 329 patients with primary cervical spine diagnoses were included. The mean age of the cohort was 56.8 ± 14.5 years. There were 183 females (55.6%) in the population and the average BMI of the entire group was 27.8 ± 6.22.

Main results

Among all included patients, 171 patients (52.0%) had CBVA, 281 (85.4%) had McGS, and 259 (78.7%) had SLS visible on their full spine radiographs (Table 1). The mean CBVA was 2.30 ± 7.69, mean McGS of 5.02 ± 8.12, and mean SLS of -1.59 ± -2.03. The CBVA correlated strongly with MGS ($r=0.83$, $p<.001$) and SLS ($r=0.89$, $p<.001$) (Table 2). The McGS was positively correlated with SLS with a correlation coefficient of $r=0.89$ ($p=.001$).

Table 1
Mean differences from the Chin-Brow Vertical Angle (CBVA) for McGregor's Slope (MGS) and the Slope of the Line of Sight (SLS) are included to facilitate interconversion from CBVA to more accessible craniocervical parameters. The percent of patients with each horizontal gaze parameter visible is included along with their respective means and standard deviations

Parameter	Mean difference relative to CBVA	Mean value±+SD	% of patients with visible parameter
McGS	1.40	5.02±8.1	85.4
SLS	3.89	−1.59±2.0	78.7
CBVA	−	2.30±7.7	52

Using linear regression modeling, strong predictive relationships were found between all the horizontal gaze parameters (Table 2).

Other analyses

Patients were subsequently stratified into those with CD (n=119) and those without (n=108). Cervical deformity patients had a mean age of 62.6 ± 13.5 years and were significantly older than the nondeformity group 53.3 ± 13.3 years ($p<.001$). The difference in McGS, gender, and BMI was similar between the 2 stratified groups.

The 2 groups differed greatly in global and regional sagittal alignment. The nondeformity group had a mean C2-C7 Sagittal Vertical Axis (cSVA) of 19.7 ± 8.52, whereas the CD group had a mean of 27.9 ± 13.7 ($p<.001$). The CD cohort had significantly larger values for parameters assessing global alignment: TPA (13.0 vs. 9.41, $p=0.005$), T2-T12 TK (-55.9 vs. -39.6, $p<0.001$), and SVA (15.7 vs. −6.50, $p<.001$). The T1-slope minus C2-C7-lordosis (TS-CL), C2 slope (C2S), PT, and PI-LL did not significantly differ between the 2 groups.

The CD patient subset was further analyzed. Sixty-three of these patients (52.9%) had CBVA measured, whereas 113 (95.0%) and 99 (83.2%) had McGS and SLS measured, respectively. These patients were then separated into those that had a small McGS ($<10˚$) and those with a large McGS ($>10˚$). Ninety-two patients met the criteria for a small McGS and 21 patients for a large McGS. Age, gender, and BMI were not statistically significant between these 2

Table 2
Linear regression analysis identifies predictive relationships between CBVA, MGS, and SLS

Predictor	Dependent variable	R	R[2]	p-value
CBVA	MGS	0.83	0.69	**<.001****
CBVA	SLS	0.89	0.80	**<.001****
MGS	SLS	0.90	0.82	**<.001****

Bold and asterisk signify statistical significance with a p-value <0.05.

subsets. Radiographic parameters differed significantly between these 2 groups including cSVA, (small vs. large MGS: 25.5 vs. 38.6, p<.001), TS-CL (18.7 vs. 39.3, p=.001), and C2S (14.4 vs. 33.6, p<.001). There were no significant differences between the 2 groups for TPA, T2-T12 TK, SVA, PT, and PI-LL.

Discussion

The role of the cervical spine in maintaining and compensating for sagittal alignment has become a growing area of interest in the adult spinal deformity literature. Furthermore, as the global population ages, there is expected to be an increase in the prevalence of spinal deformity [16]. The purpose of this study was to correlate CBVA, a parameter that is not readily visible, with SLS and McGS in the setting of cervical spine pathology. This study presents evidence in support of our original hypothesis that these occipitocervical angles have linear relationships and may be used as surrogates for one another.

Our initial patient cohort was defined by those with a primary cervical diagnosis including, cervical radiculopathy, cervical myelopathy, CD, cervical instability, and cervicalgia. The etiology of these diagnoses stem from degenerative changes of the cervical spine. These changes typically occur as patients' age and are associated with disc space narrowing, facet arthropathy, and loss of the physiologic lordosis of the cervical spine [17]. The loss of lordosis can contribute to dynamic spinal cord compression and myelopathy in addition to disc herniation, facet and ligamentum hypertrophy [18,19]. Cervical radiculopathy is another result of degenerative changes of the spine. In these cases, patients present with a variety of findings including sensory and motor deficits [20]. Surgical intervention in cases of cervical radiculopathy typically involves decompressive measures to restore alignment and relieve symptomatology [20]. Another such degenerative change is degenerative cervical spondylolisthesis. Alignment is critical in degenerative cervical spondylolisthesis, as recent studies have found significant correlations between large T1-slopes and larger CL curvature [21]. Furthermore, cervical degeneration has repercussions on the development of myelopathy and malalignment, which has been implicated as a possible etiology in neurological dysfunction [17]. Thus, in these cases of degenerative cervical spine conditions, alignment plays a pivotal role. The prototypical measurement used to assess cervical curvature in these cases is C2-C7 CL [22,23]. Cervical lordosis is age-related and is therefore, difficult to generalize across various patient populations [24]. Additionally, several studies have shown that few patients present solely with C2-C7 lordotic malalignment, and that there may in fact be other parameters at play [24]. Through our study, we bring to the forefront a more accessible measurement for the assessment of cervical spine alignment.

Chin-Brow Vertical Angle is the most common parameter used to assess horizontal gaze [4]. It is defined as the angle subtended between a line drawn from the patient's chin to brow and a vertical line and is measured when the patient's hips and knees are extended [4,25]. The CBVA has been routinely used in clinical practice, mainly in the setting of ankylosing spondylitis [5,26]. Although CBVA may be measured clinically in the office setting, assessing this parameter on radiographs provides several advantages. Firstly, it serves as a reference point which clinicians and surgeons may refer to as it is part of the patient's medical record. Secondly, this assessment can be made before the patient encounter allowing for maximum time spent with the patient without the need to assess the clinical version of the CBVA. Lastly, radiographic evaluation of this measurement allows the surgeon to view the osteology of the cervical spine and provides a more thorough assessment of contributors to this deformity and measurement.

Only recently has CBVA begun to emerge as a possible parameter that can be used in the context of cervical pathology, being shown to correlate with frailty in CD patients [27]. In the current study, only 171 (52%) of patients with a cervical spine diagnosis had sufficient landmarks to allow for CBVA to be measured; similarly, only 63 (52.9%) of patients in the CD group had CBVA measured in our EOS database. The SLS and McGS, however, are 2 parameters that are more readily measured on radiographic imaging. The SLS was present in 259 patients (78.7%) of our entire cohort, and in 99 patients (83.2%) of the deformity subset. The McGS was present in 281 patients (85.4%) of the entire cohort and in 113 patients (95.0%) of the deformity subgroup. In the cases where sagittal deformity leads to the chin and brow falling out of the EOS imaging column, the SLS and more commonly the McGS are more visible. In the case of SLS, sometimes the brow can be cut off but not the inferior orbit. In the case of the McGS, the brow, orbit and the chin can be cut-off but the posterior edge of the hard palate and the bottom of the occiput are often visible.

Therefore, SLS and McGS are more accessible on full-length standing stereoradiographs. The radiographic method used in this database, EOS, uses an ultrasensitive multiwire proportional chamber detector to detect X-rays, allowing for simultaneous anteroposterior and lateral images of the whole body to be taken [28]. It has 2 perpendicularly situated radiation sources and detectors which capture these 2 perspective radiographs [29]. The fact that even with full-body stereoradiographs almost half of the cohort did not have a measurable CBVA is likely caused by width limits on the detector field. In addition to the increased accessibility of SLS and McGS, we also found that these parameters correlated very strongly with each other and with CBVA—the prototypical measure of horizontal gaze in the setting of spine pathology. The angles were computed for the means of the cohort because a significant portion of the patients in the study did not have all 3 parameters. We therefore correlated these parameters with matched cohorts and further subdivided to create a homogenous group of patients to assess the correlation of these parameters. If the statistical analyses were

conducted for each patient there would be an insufficient number of data points caused by the paucity of measurements of these parameters. By using the mean difference between these 3 parameters, one is able to approximate the CBVA by measuring one of the surrogates. For example, the mean difference between McGS relative to CBVA is 1.40. Therefore, a McGS of 5 corresponds to a CBVA of 6.4 (McGS+1.40=CBVA). Similarly, an SLS of −1.5 corresponds to a CBVA of 2.39 (SLS+3.89=CBVA). Thus, SLS and McGS can serve as surrogate markers for CBVA, which will broaden the use and relevance of CBVA outside of the realm of ankylosing spondylitis and rigid cranio-cervical junction deformity. Additionally, we show that measuring horizontal gaze is feasible if surrogate measures are used, with McGS being the most visible of the parameters in question.

There are limitations to the present study. Firstly, this is a retrospective radiographic analysis. This study solely analyzes the baseline view of these radiographic parameters; postoperative data and follow-up can further delineate their accessibility. This study does not provide the direct clinical relevance of measuring horizontal gaze either in general cervical pathology or in CD, caused by the absence of health-related quality of life data in our cohort. Nevertheless, the patient cohort was collected prospectively and consecutively and this study is the first to report the accessibility of these horizontal gaze parameters among patients with the full spectrum of cervical pathologies.

Previous studies have found similar correlations for CBVA with SLS and McGS in the setting of patients with thoracolumbar deformity. Lafage et al. reported similar correlation coefficients and statistical significance (r>0.8, p<.001) for these parameters [11]. Our study reaffirms the results reported in literature regarding the role of SLS and McGS as proxies for CBVA [11,30,31]. However, this is the first study to bring to light the role of CBVA as a marker solely in the setting of cervical spine pathology and CD with the mean difference of 2 surrogate markers.

Conclusions

The role of CBVA has previously been limited to the settings of ankylosing spondylitis and thoracolumbar deformity as a method of assessing horizontal gaze. The CBVA is not routinely measured or accessible in clinical practice beyond this scope. This study demonstrates that surrogate radiographic markers such as McGS and SLS can be used to assess horizontal gaze in patients with primary cervical pathologies where CBVA is otherwise not visible. Furthermore, we have provided the mean difference for these measurements, allowing an ease of conversion between these parameters thus broadening the use of CBVA in assessing cervical spine pathology.

Acknowledgments

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