Original Article

Does cranial incidence angle have a role in the tendency toward cervical degenerative disc disease?

ABSTRACT

Purpose: The purpose is to investigate if a correlation existed between the frequency of cervical degenerative disc disease occurrence and cranial incidence (CI) angle.

Materials and Methods: A retrospective analysis of case series. Sagittal parameters of the case series were compared with the sagittal parameters of the same number of consecutive patients with neck pain only but no cervical degenerative disc disease (CDDD). Moreover, CI angle values were noted to be significantly different among groups on variable-based examination. Furthermore, the cervical lordosis (CL) values of men were observed to be significantly different. Therefore, the significant intergroup differences related to the CI angle and CL values support the study hypothesis.

Results: No intergroup differences were noted regarding gender and age distribution ($p = 0.565$; $p = 0,498$). A significant intergroup difference was observed regarding CS values and the mean vector of CI angle and CL values for men and women ($p = 0.002$). CI angle values were noted to be significantly different among groups upon variable-based examination ($p < 0.001$). The CL values of men were observed to be significantly different, but not the CL values of women ($p = 0.850$). Therefore, the significant intergroup differences related to the CI angle and CL values support the study hypothesis.

Conclusions: A reverse correlation between CI angle and CDDD development is demonstrated. This correlation is valid between CL and CDDD development. Therefore, cervical sagittal profile and the CI angle and CL measurements should be performed to follow-up patients with cervical pain.

Keywords: Cervical spine, eye gaze, intervertebral disc degenerations, lordosis, spinal curvatures

INTRODUCTION

Humans are the only vertebrate mammals that can naturally maintain the upright position for a reasonably long time by using harmonic cycles of anatomical pendulum.[1,2] This natural ability is primarily provided to human beings by the secondary or lordotic curves. In addition, this bipedalism needs some modification of gaze direction through adjustment of the foramen magnum orientation and its relationship with the cervical spine.[3] Nevertheless, this bipedalism in humans is responsible for various degenerative diseases of the spine, such as intervertebral disc herniations.[4,5] An understanding of the significance of sagittal contour in the progression of degenerative spine disease has led to the elucidation of several sagittal parameters. Some of these parameters remain constant throughout the lifetime, such as the cranial incidence (CI) angle. The main objective of this study was to investigate if a correlation existed between the frequency of cervical degenerative disc disease (CDDD) occurrence and CI angle,

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with CI angle being a constant individual parameter, unlike other definitive individual parameters.

Hypothesis

As the CI angle value increases, the frequency of CDDD occurrence decreases within the normal limits of the CI angle. In other words, CDDD is observed more frequently among those people who have a low CI angle.

Basis of hypothesis

Notably, CI angle = cranial tilt (CT) + cranial slope (CS),[6] with a high CI angle related to high CT or CS, and therefore, it should be related to high cervical lordosis (CL). Changes in the sagittal alignment of the cervical spine were noted to affect the kinematics.[7] In addition, a high degree of T1 slope of more than 25° can most likely cause positive sagittal balance because of the increased sacral vertical axis.[8] Therefore, it could be concluded that people with a high CI angle simultaneously have a high CL, with a lower frequency of CDDD. How a correlation between the degenerative disease process and a constant intrinsic parameter could be possible is explained in detail in the discussion section.

MATERIALS AND METHODS

Patients

This study is a retrospective analysis of case series. In this analysis, sagittal parameters of the case series were compared with the sagittal parameters of the same number of consecutive patients with neck pain only but no CDDD. Group I (G-I) comprised 100 patients with CDDD who underwent anterior cervical discectomy and fusion (ACDF), and Group II (G-II) had 100 consecutive patients who had neck pain but no CDDD. A cervical spine magnetic resonance imaging, sagittal reformatted cervical spine CT, and direct roentgenograms of all patients were performed. Neurological examinations and operations were performed by the author, and the final evaluation of patients and the decision on surgical indication were undertaken by the surgical board of the Institution.

Inclusion criteria

This study included 100 consecutive adult male and female patients with CDDD at one or more spinal levels operated in the Neurosurgery Clinics of our Hospital between September 2014 and December 2016, as well as 100 consecutive adult male and female patients with only neck pain who were seen at the outpatient clinic between August 2016 and December 2016.

Exclusion criteria

Patients with spinal deformities, such as scoliosis and kyphosis; those with ossified posterior longitudinal ligament, tumor, and trauma; and patients with severe systemic diseases such as diabetes, chronic pulmonary diseases, or malignancy were excluded from the study. Patients under 18 years of age were not included in the study because of their developing spinal morphology. In addition, elderly patients above 65 years were not included in the study because of their natural age-related spinal degenerations that could change some sagittal parameters and alignment.

Sagittal parameters and measurements

Cranial incidence angle

The angle between the center of the line perpendicular to the McGregor line and the line that joins the middle of the McGregor line to the sella turcica on the lateral cervical roentgenogram [Figure 1a].[6]

Cervical lordosis angle

The angle between the line parallel to the C2 posterior margin and the line parallel to the C7 posterior margin on the lateral cervical roentgenogram [Figure 1b].[9]

Cranial slope

The angle between the horizontal line and the McGregor line on the lateral cervical roentgenogram [Figure 1c].[6]

Statistical analysis

This study performed a multivariate analysis. Statistical analysis was performed using IBM SPSS Statistics for Windows, Version 22.0. (Armonk, NY: IBM Corp) with special macros. Descriptive statistics of all variables in the study (mean, standard deviation, median, minimum and maximum values, and percentile) were calculated. Kolmogorov–Smirnov and Mardia's Multivariate Kurtosis and Skewness tests were used, respectively, to evaluate the uni- and multivariate normality

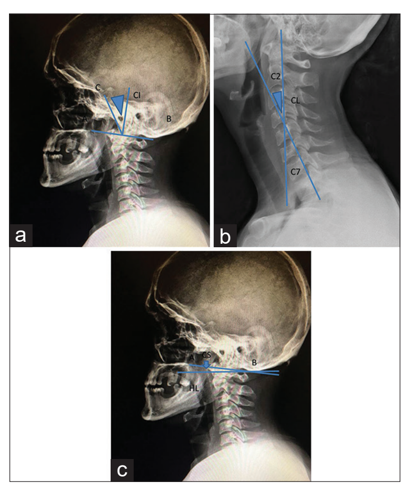

Figure 1: CI angle (a), CL (b) and CS (c) measurements on the lateral cervical roentgenogram (a: Hard plate; b: Opistion; c: Sella Turcica; CI - Cranial incidence angle, CL - Cervical lordosis angle, CS - Cranial slope)

assumptions for quantitative variations. Groups' homogeneity related to age and sex distribution was evaluated using Mann–Whitney U and Chi-square tests. Permutational multivariate analysis of covariance (PERMANCOVA) (distance, resemblance: Euclidean distance, *post hoc*: pairwise test, Bonferroni *t*-test, a homogeneous subset) was used to evaluate the effects of covariates, such as age and gender, during intergroup comparisons for simultaneously obtained CI, CS, and CL values.

RESULTS

The overall study population consisted of 200 patients, 41% men, and 59% women. G-I consisted of 39 men and 61 women, with M/F of 0.64. G-II consisted of 43 men and 57 women, with M/F of 0.75. No intergroup differences were noted regarding gender distribution ($P = 0.565$). The median ages of G-I and G-II were 42.5 years (min: 21 years, max: 65 years) and 44.5 years (min: 27 years, max: 65 years), respectively. Moreover, no intergroup differences were noted related to age distribution ($P = 0.498$).

The mean and median CI, CL, and CS values of groups are presented in Table 1. A significant intergroup difference was observed regarding CS values. Therefore, CS data were excluded from the data set for multivariate analysis. PERMANCOVA results of the other two parameters (CI angle and CL) are presented in Table 2. According to the multivariate analysis, significant intergroup differences were noted regarding the mean vector of CI angle and CL values for men and women ($P = 0.002$). Moreover, both men's and women's CI angle values were noted to be significantly different among groups on variable-based examination ($P < 0.001$). Furthermore, the CL values of men were observed to be significantly different, but not the CL values of women ($P = 0.850$). Therefore, the significant intergroup differences related to the CI angle and CL values support the study hypothesis.

Table 1: Frequency distribution of cranial insidence angle, cervical lordosis and cranial slope values of the groups

Group	Gender	*n*	Mean±SD	Median	Minimum-maximum
CI					
I	Male	43	25.52±3.95	25.90	17.00-33.80
	Female	57	25.41±3.53	24.80	16.70-31.60
	Total	100	25.46±3.70	25.30	16.70-33.80
II	Male	39	23.45±4.39	23.70	15.30-33.60
	Female	61	23.49±3.72	23.70	16.80-32.70
	Total	100	23.47±3.97	23.70	15.30-33.60
Total	Male	82	24.53±4.27	24.60	15.30-33.80
	Female	118	24.42±3.74	24.55	16.70-32.70
	Total	200	24.46±3.95	24.55	15.30-33.80
CL					
I	Male	43	17.23±5.15	17.30	0.00-27.10
	Female	57	14.29±7.07	16.40	−2.10-24.30
	Total	100	15.56±6.45	16.95	−2.10-27.10
II	Male	39	12.83±8.00	14.80	−4.30-26.30
	Female	61	14.46±7.22	14.20	−6.40-26.20
	Total	100	13.83±7.54	14.35	−6.40-26.30
Total	Male	82	15.14±6.98	16.50	−4.30-27.10
	Female	118	14.38±7.12	14.80	−6.40-26.20
	Total	200	14.69±7.05	15.75	−6.40-27.10
CS					
I	Male	43	7.77±3.70	7.90	−7.30-13.80
	Female	57	6.22±4.84	7.70	−8.10-13.50
	Total	100	6.89±4.43	7.80	−8.10-13.80
II	Male	39	5.52±8.53	7.20	−12.90-19.30
	Female	61	6.67±7.72	6.00	−13.50-19.40
	Total	100	6.22±8.02	6.60	−13.50-19.40
Total	Male	82	6.70±6.52	7.85	−12.90-19.30
	Female	118	6.45±6.47	7.15	−13.50-19.40
	Total	200	6.55±6.47	7.65	−13.50-19.40

CI - Cranial insidence angle, CL - Cervical lordosis angle, CS - Cranial slope, SD - Standard deviation

Table 2: Permutational multivariate analysis of variance results of cranial incidence angle and cervical lordosis values

Terms	Df	SS	Pseudo-F	*P* (permutation)
Group	1	477.38	9.65	0.002
Gender	1	120.24	2.43	0.090
Age	1	2549	51.55	0.001
Group × gender	1	323.09	6.53	0.006
Residual	195	9642.7		
Total	199	13112		

Number of permutations: 997-999. Df - Degree of freedom, SS - Sum of squares (type I)

DISCUSSION

Bipedalism or upright posture is ergonomic, improves survivability and stability, and is an exclusively human characteristic.[10] The complex structure of the cervical spine provides greater mobility and helps carry the head. An optimal arrangement of sagittal cervical and head profiles provides proper horizontal gaze and least minimum energy expenditure to sustain this. Nevertheless, these structural and motion complexities of this most mobile part of the spinal column are associated with various pathologies. Until date, several hypotheses have been postulated regarding progression to bipedality during the evolution of humans. During the prolonged course of evolution from quadrupled ancestor to erect human beings, achieving bipedalism would have required several adaptive mechanisms, including changing of joint orientation. Notably, in spinal joints, this orientation would have changed toward developing a functional and comfortable horizontal gaze. Dart RA suggested the "watching out hypothesis" in 1959,[11] which stated that the visual gains of being able to inspect the environment could have encouraged the adoption of the upright posture in humans. The acquisition of upright posture and adoption of a straight horizontal gaze would have developed together during the evolution. Both these developments were noted to have happened over the prolonged duration in the history of human evolution. During this evolution, some structures would have helped achieve these features through anatomical changes – the shape and orientation of intervertebral joints being the most crucial ones. Moreover, the shape of the sagittal contour of the spine would have changed concordantly. Simultaneously, the foramen magnum orientation must have adapted to the shape of the upper cervical spine and the need of a straight horizontal gaze.[12] Notably, the location of the foramen magnum, related to the longitudinal axis of the head, and its orientation has been examined in humans and some ape species. The position and inclination are quite invariant among humans, but the location and inclination of foramen magnum were repetitively and statistically different in various ape species.[13] Hence, the transformation and adaptation of erect position (foramen magnum orientation and horizontal gaze direction) in humans represent the crux of the evolution.[3] Notably, the results of some cephalometric studies in the literature have evidenced the intimate relationship between head posture and cervical spine.[13-15]

Any degenerative spine disease, including CDDD, is a dynamic state that results from alteration, with a continuous alteration causing deviations from normality. Mechanical forces play a primary role in creating a transformation course. The imbalance of these forces might result in some degree of deviation even if the force magnitude is small.

If these predictions are accurate, then the development of CDDD would be relatively more in individuals who have misaligned cervical sagittal profile than those with normal sagittal cervical profiles. Because thoracic kyphosis is associated with the anterior inclination of the cervical region,[16] the head posture needs to be aligned to normalize the horizontal gaze. In addition, intrinsic cervical region malalignments need to be adjusted to position the head for a horizontal gaze. Therefore, the mechanical stresses involved might accelerate the cervical spine degeneration, thereby causing CDDD. The present study was designed based on this probability. The new perspective regarding the sagittal balance of the spinal cord in the lumbosacral area helped us to formulate the study hypothesis.

The results of this study demonstrated that a smaller CI angle increases the risk of developing CDDD. This phenomenon is valid for the CL angle, too.[17] Hence, individuals with smaller CI angle or CL values might have to strain more to maintain horizontal gaze direction within normal limits than those with higher CI angle or CL values. Notably, no intergroup differences were noted regarding the CS angle. Therefore, CS values might not be a crucial parameter to assist in the follow-up of a patient with cervical symptoms. Notably, loss of CL during the lifetime or a small CI angle might induce degeneration because of changing kinematics. The literature revealed that the T1 slope had been investigated extensively earlier.[7,8] The mean CL in the upright position in a healthy population is between 31° and 54°.[12,18] The present study observed that the mean values of CL were 13.83° and 15.56° in G-I and G-II, respectively. These values were significantly lower than those of healthy individuals. The lower values in G-II are expected because this group comprised patients with cervical pain and not completely healthy persons. The mean age of patients was 44.50 years and 43.36 years in G-I and G-II, respectively. The mean age is significantly different from that of the study on healthy individuals. Therefore, degenerative changes worsening with aging is a well-known phenomenon. A decrease in CL could occur parallelly with an increase in age. Notably, a decrease in CL may cause stress on the subaxial level, probably at the pivotal C5–C6 and C6–C7 segments.[7] In parallel to this, maintaining a horizontal gaze in individuals with a low CI angle requires extra forces toward the pivotal region of the cervical spine. These stress forces can accelerate the degenerative process at these levels. This fact can, therefore, explain the reason for most CDDDs at these levels. Variations in sagittal profiles or its changes over time affect the kinematics of the cervical spine, subsequently initiating a modification of the loading pattern of these segments and accelerating their degeneration. Cervical sagittal parameters, including CL, normalizing after ACDF[19,20] might support the hypothesis. Several studies in the literature have evidenced that reconstruction of cervical alignment with decompression of the spinal cord provides excellent outcomes.[9,19,20] Sagittal balance maintains the standing position with a minimum muscular strength.[21] The alignment of the cervical spine is the result of forces on bony elements and discs during development. Bony development of the spine is completed by adulthood, and imbalanced forces affect the intervertebral discs primarily after this stage.[22] Consequently, disc degeneration increases with the degenerated disc deforming under physiologic forces.[23] In light of all these phenomena, CDDD development can be expected to be frequent among individuals who have a low CI angle than those who have a high CI angle within normal limits.

Limitations of the study

The present study was conducted retrospectively. Hence, the control group comprised patients with cervical pain rather than healthy subjects. This study considers only a part of the sagittal profile. Therefore, considering some compensatory mechanisms along with thoracic and lumbar regions of the spine and determining the global sagittal balance might provide a better perspective.

CONCLUSIONS

This study demonstrated a reverse correlation between CI angle and CDDD development if the CI angle values are within normal limits. In addition, this correlation is valid between CL and CDDD development. Therefore, the cervical sagittal profile and the CI angle and CL measurements, in particular, should be performed to follow-up patients with cervical pain. However, CS might not be an essential measurement in this regard. Notably, correction of the cervical sagittal balance should be considered during any decompressive surgery to the anterior cervical spine.

Consent for publication

Patients signed informed consent regarding publishing their data and photographs.

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Conflicts of interest

There are no conflicts of interest.

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