Does atlantoaxial dislocation influence the subaxial cervical spine?

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Received: 23 February 2011 / Revised: 5 September 2012 / Accepted: 5 March 2013 / Published online: 23 April 2013
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Abstract

Introduction Previous studies have reported that the alignments of the occipital-cervical and subaxial spine were closely interrelated in asymptomatic individuals; however, none have focused on a population with atlantoaxial dislocation.

Material and methods From 2007 to 2011, 298 patients with atlantoaxial dislocation and atlas occipitalization were studied. Angles formed between Occiput-C2 and C2–C7 were measured. The relationship between the alignment of the occipital-cervical junction and the subaxial cervical spine was evaluated.

Results The range of values for the angles measured was as followed: the Occiput-C2 angles were -35.2° to 44.8° , and the C2–C7 angles were -17.4° to 77.8° . Statistically significant negative correlations were observed between the Occiput-C2 and C2–C7 angles.

Conclusion Anterior dislocations of the atlas are associated with diminished lordosis or even kyphosis of the occipital-cervical junction, and result in compensatory hyperlordosis of the subaxial cervical spine, collectively

presenting as a “swan neck” deformity. Atlantoaxial dislocation may influence the global cervical alignment.

Keywords Atlantoaxial dislocation · Atlas occipitalization · Basilar invagination · Cervical alignment

Introduction

Atlantoaxial dislocations (AAD), although uncommon, are associated with complex deformities of the cervical spine, significant risk of neurological deterioration, and typically require surgical treatment [1–3, 12]. We noticed that severe AAD was always associated with kyphosis of the occipital-cervical junction, and resulted in compensatory hyperlordosis of the subaxial cervical spine, collectively presenting as a “swan neck” deformity. In this setting, questions arise during the occipital-vertebral surgery: does atlantoaxial dislocation influence the subaxial cervical alignment? Is anatomic reduction necessary for atlantoaxial dislocation? Despite this, very little information is available concerning cervical alignment in individuals living with this pathologic condition. To our knowledge, there is no prior study to examine these relationships in such a population.

Significant relationships between the alignments of the upper and subaxial cervical spine have been clearly established in asymptomatic subjects. In separate studies, Nojiri et al. [7] and Sherekar et al. [9] both demonstrated that a statistically significant negative correlation existed between the Occiput-C2 and C2–C7 angles in normal subjects. Among AAD patients, it has been shown that occipital-cervical or atlantoaxial fusions that place the upper cervical fusion in a hyperlordotic position can lead to subaxial cervical spine kyphosis and swan neck deformity, as well as altered kinematic patterns [5, 10, 11]. However,

Approval by the authors’ institutional review board (IRB) was obtained.

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no previous study has examined such parameters in patients with AAD prior to surgical intervention. In the setting of AAD, the cervical alignment may retain its different status compared with those among normal individuals.

The purpose of this study was to characterize the relationship between the alignment of the occipital-cervical junction and subaxial cervical spine in a population with AAD. We anticipated that strong correlations would exist between these variables. This information will provide us with radiographic parameters and further will help us understand the complex deformities that occur in patients with such pathology.

Methods

Patient demographics

From January 2007 to October 2011, a total of 298 patients with a diagnosis of AAD and atlas occipitalization were recruited in our spine center (Peking University Third Hospital), and informed consent was signed. Among them, 166 were males and 132 were females. The ages ranged from 4 to 72 years, with a mean of 35.4 years. The patients had experienced symptoms for an average 43 months (range 3 months to 40 years) prior to enrollment. The atlantodental interval ranged from 5 to 22 mm, with a mean of 8.2 mm.

Determination of alignment

All patients underwent lateral X-rays with their neck in the neutral and relaxed position. The images were obtained with the patients standing and looking straight ahead. The distance between the film and the tube was set at 1.5 m.

Measurement of radiographic parameters

Three standard lines were made on the neutral lateral X-rays that were obtained. We randomly chose lordotic curves to be expressed as positive values, while kyphotic curves were given negative values.

- Line A represented McGregor's line [6], and was measured from the solid palate to the inferior edge of the occiput.
- Line B represented the inferior endplate of the axis, while
- Line C represented the inferior endplate of C7.

The angles formed between these lines (Occiput-C2 and C2–C7) were measured (Fig. 1), using Rhinoceros® (Robert McNeel & Associates, Seattle, WA, USA)

Fig. 1 Measurements of the angles on the neutral lateral X-rays

Fig. 2 Correlation coefficient of angulation between the Occiput-C2 and C2–C7 ($Y = 25.648 - 0.688X$, $R^2 = 0.414$, $P = 0.000$)

Table 1 Correlation of the angles, age and disease process (Pearson test)

	Age	Disease process
Occiput-C2	$P = 0.141$	$P = 0.322$
C2–7	$P = 0.708$	$P = 0.191$

software. The measurements were performed in blinded manner, repeated three times by three authors on three separate occasions, and the results were then averaged. To evaluate the intraobserver and interobserver reliability of these measurements, in the first 197 cases, the intraclass correlation coefficient (ICC) was assessed from the results of the three observers that were taken on two occasions separated by a 2-week interval. Secondly, measurement of the Pearson correlation coefficient was used for the assessment of the linear relationship between these angles.

Fig. 3 A 33-year-old male with atlantoaxial dislocation and occipitalization. **a** X-ray showed severe dislocation and swan neck, with Occiput-C2 angle of -7.1° and C2–7 angle of 36.6° . **b** CT scan showed that C5–6 disc (the apex of the lordotic curve) had posterior osteophytosis (yellow arrow) and some sclerosis of vertebral plates.

c–e MRI revealed C5–6 disc degeneration and herniation. **f** After atlantoaxial reduction and fixation, the swan neck deformity was corrected, with Occiput-C2 angle of 1.5° and C2–7 angle of 18.7° . **g–i** Post-operative MRI revealed C5–6 disc herniation decreased evidently after the swan neck correction

In addition, the correlation coefficient between age, angulations, and morbidity period of AAD was also evaluated. The statistically significant level was set at <0.05 with 95 % confidence intervals (SAS, version 9.1, NC, Inc.).

Results

1. *Reliability of the measurements* In the first 197 cases, the results showed excellent intraobserver (ICC = 0.92, 0.90 and 0.96) and interobserver correlation coefficient (ICC = 0.92).
2. *Measurements of the angles* The range of values for the angles measured was as followed: the Occiput-C2 angles were -35.2° to 44.8° , and the C2–C7 angles were -17.4° to 77.8° .
3. *The relationship between alignment of occipital-axial and subaxial cervical spine (linear line)* A significant negative correlation was observed between the Occiput-C2 and C2–C7 angles ($P = 0.000$, Figs. 2, 3).
4. *Correlation of the angles, age, and morbidity period* We found that the admission age had no significant correlation with the angle of Occiput-C2 and C2–C7, as well as the morbidity period ($P > 0.05$, Pearson test) (Table 1).

Discussion

Normal values for sagittal alignment in an adult population have been established in the past. These include lordosis of the atlantoaxial joint ranging from 25.6° to 28.9°, lordosis of the occipital-axial angle ranging from 14.5° to 16°, and subaxial (C2–C7) lordosis ranging from 9° to 16° [4, 5, 7, 9]. Therefore, when the head is maintained in the neutral position, the alignment of the cervical spine is kept in slight lordosis to achieve overall balance [8]. Previous studies have also established a strong correlation between the alignments of the upper and lower cervical spine among normal individuals. Nojiri et al. [7] and Sherekar et al. [9] both demonstrated a statistically significant negative correlation observed between the Occiput-C2 and C2–7 angles in normal adults. A similar relationship was found between the C1–2 and C2–7 angles, although this relationship was not quite as strong [7, 9].

In this study among patients living with a known pathologic state of AAD and atlas occipitalization, our results also demonstrated that the alignments of the occipital-cervical junction and subaxial cervical spine were highly correlated (Fig. 2). The overall relationship seemed to be that as the lordosis of the occipital-axial angle was diminished, or even reversed to a kyphotic angle, the alignment of the subaxial cervical spine became increasingly lordotic. The converse of this statement was also true, with increasing occipital-axial angles correlating with decreasing subaxial lordosis.

The direction of the dislocation was also found to be an important determinant of cervical spine alignment. In this series, the majority of patients had anterior AADs. We found that patients with anterior dislocations of the atlas generally had a kyphotic alignment in occipital-cervical junction, with hyperlordosis of the lower cervical spine. The hyperlordosis was thought to serve as compensation to achieve global balance, and this combination of curvatures has been referred to as a “swan neck” deformity [10]. In contrast to the findings in those with anterior dislocations, the alignment of the subaxial cervical spine in patients with posterior dislocations of the atlas was shown to be straight, or even kyphotic, thus reversing the physiologic lordosis. These findings imply that the primary compensation is to achieve overall balance, and that the response of the subaxial c-spine is not fixed and varies to achieve this goal.

In normal patient populations, significant relationships between cervical alignment and the age of the patient have been found. In a normal population, aging results in the occipital-axial angle gradually decreasing, regardless of gender, while the angle between C2 and C7 tends to increase [4, 5, 7]. In contrast, we found that among individuals with AAD, this tendency did not necessarily occur. The age at the time of admission did not have any

significant correlation with the angles formed between Occiput-C2 and C2–C7. These findings seem to demonstrate that compensation for the deformity created by chronic AAD overrides the normal physiologic changes that occur during the aging process.

Based on the findings, complete atlantoaxial reduction and “swan neck” correction should be the goal of surgical planning and execution in the treatment of occipitalization and AAD. More specifically, following surgical intervention the angle between the Occiput and C2 should be corrected to approximately 15° with an anatomic reduction of atlantoaxial joint obtained. Achieving these surgical goals will provide the best opportunity for such patients to obtain an ideal global balance.

The major limitation of this study is that the current study was a two-dimensional analysis based on lateral X-rays, and the factors of rotational and vertical dislocation were not considered. Another significant limitation of this study is the lack of correlation between radiographic findings and clinical symptoms. This would be particularly useful when assessing the relationship between cervical spine alignment and cervical disc degeneration. Finally, only 298 cases were included in the current study.

Despite these limitations, these values can be used as clinical parameters in a population of patients with chronic AAD that are scheduled to undergo occipital-cervical fusion. In the future, we would like to study the changes that occur in these radiographic parameters following their surgical intervention.

Conflict of interest None.

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