



Original Article

Relationship between odontoid fracture angle and cervical sagittal balance

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ABSTRACT

Background: Fractures can occur in various locations within the odontoid process with differing orientations. However, little is known about what factors contribute to the anterior versus posterior angles/orientation of these fractures.

Methods: We evaluated 74 patients with odontoid fractures (2013–2018) from a single-institution. Patients' fracture angles/orientations were measured on computed tomography studies, and were grouped into oblique posterior (OP) or oblique anterior (OA) groups. We also took into account cervical sagittal balance utilizing upright x-rays. Other variables studied included patients' ages, sagittal balance measurements, and the mechanisms of injury.

Results: Fracture angles were significantly steeper in the OP group. OP fractures had larger C2-C7 sagittal vertical axis, occiput-C2 angles, and occiput-C7 angles versus anteriorly oriented fractures. In our linear regression model, advanced age and large occiput-C2 angles were predictive of the odontoid fracture angle. Patients who sustained ground-level falls also had significantly steeper fracture angles versus those involved in motor vehicle accidents.

Conclusion: The odontoid tends to fracture at a steep, posterior angle in elderly patients who demonstrate a large positive sagittal balance when the head is extended following a ground-level falls.

Keywords: Angulation, Cervical spine, Dens, Fracture, Odontoid, Sagittal balance

INTRODUCTION

Odontoid fractures are common cervical spine traumatic fractures and there is no clear agreement regarding the optimal management strategy.^[3-6] Here, we assessed whether the angle/orientation of odontoid process fractures was best determined by the patient's pre-existing cervical sagittal balance. This required assessment of; C2-C7 sagittal vertical axis (SVA), C2-C7 angle (cervical lordosis), T1 slope, McGregor's slope (McGS), occiput-C2 angle, occiput-C7 angle, and cervical mismatch (T1 slope minus C2-C7 angle).

MATERIALS AND METHODS

This study was performed with institutional review board approval, utilizing multiple inclusion/exclusion criteria [Table 1].

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Table 1: Inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
Odontoid fracture (any Anderson type) ^[1] Sagittal CT scan at the time of the injury	no upright cervical spine x-ray C7 not visible on x-rays

CT: Computed tomography

Clinical data

Patients with odontoid fractures averaged 76 years of age (2013–2018). The Anderson fracture types/odontoid fracture angles were measured utilizing computed tomography (CT) scans, while cervical sagittal balance was based upon standing/sitting cervical spine X-rays [Figures 1a and b].^[1] Fractures included Anderson type II fractures 60 (81.1%) and Type III fractures 14 (18.9%). Eleven patients (14.9%) had anteriorly oriented fractures, while 63 patients (85.1%) had posterior fractures. Traumatic injuries included: 52 (70.3%) ground-level falls, 14 (18.9%) falls from height, one unknown type of fall, and 7 (9.5%) motor vehicle accidents (MVAs). Other variables studied included: the odontoid fracture angle/orientation, C2-C7 SVA, C2-C7 Angle (Cervical Lordosis), T1 slope, McGS, Occiput to C2 and Occiput to C7 angles, and Cervical Mismatch [Table 2 and Figure 1].

Statistical analysis

All statistical analysis was performed using SPSS (SPSS Inc., IBM, Chicago, IL), independent samples *t*-tests, linear regression models, one-way ANOVA of the multiple variables under consideration.

RESULTS

The odontoid fracture angles were significantly steeper for posterior versus anterior fractures (40.57 vs. 17.03, $P = 0.000$). There were also significant differences in C2-C7 SVA, O-C2 angle, and O-C7 angle between oblique anterior (OA) versus oblique posterior (OP) fractures [Table 2]. The mean C2-C7 SVA for OP fractures was significantly larger versus OA fractures (40.37 vs. 29.45) [Table 3]. Only age showed a significant impact on the regression model including all variables. Using O-C2 angle and age predicted odontoid fracture angles with an R^2 value of 0.21 ($P = 0.000$). Linear regression using all variables generated an R^2 value of 0.23 ($P = 0.014$). There was a significant difference in the mean fracture angle between patients suffering ground-level falls versus MVA; the mean dens fracture angle for the ground level fall group was 40.23°, while the mean fracture angle for the MVA group was 18.45° ($P = 0.002$).

Table 2: Description of measurements used for odontoid fracture angle and cervical sagittal balance.

Measurement	Description
Odontoid fracture angle	Measured in midline sagittal view on CT. Angle between inferior endplate of C2 and odontoid fracture line
Odontoid fracture orientation	Fractures with lowest point on the anterior aspect of the odontoid are OA and fractures with the lowest point on the posterior odontoid are OP
C2-C7 SVA	Distance between vertical line centered at the inferior endplate of C2 and the posterior superior corner of C7. Positive if center of C2 is anterior to C7
C2-C7 Angle (Cervical Lordosis)	Angle between inferior endplate of C2 and inferior endplate of C7. Positive value is lordosis. Negative value is kyphosis
T1 Slope	Angle between superior endplate of T1 and a horizontal line
McGS	Angle between line drawn from the hard palate to the base of the occiput and a horizontal line. Angle superior to the horizontal is positive
Occiput-C2 angle	Angle between line drawn from the hard palate to the base of the occiput and the inferior endplate of C2. Lordosis is a positive value
Occiput-C7 angle	Angle between line drawn from the hard palate to the base of the occiput and the inferior endplate of C7. Lordosis is a positive value
Cervical Mismatch	Subtract C2-C7 Angle from T1 Slope

CT: Computed tomography; OA: Oblique anterior; OP: Oblique posterior; SVA: Sagittal vertical axis; McGS: McGregor's slope

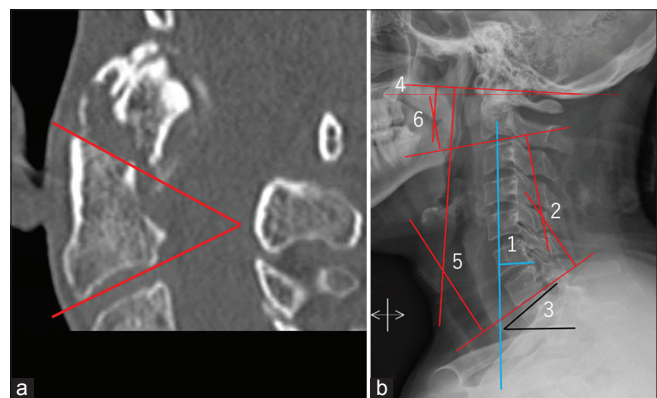


Figure 1: (a) Mid-sagittal computed tomography (CT) demonstrating odontoid fracture angle measurement. (b) Cervical sagittal balance measurements key. (1) C2-C7 sagittal vertical axis (SVA), (2) C2-C7 angle (cervical lordosis), (3) T1 slope, (4) McGregor's slope (McGS), (5) Occiput-C7 angle, (6) Occiput-C2 angle.



Figure 2: An illustrative case of a patient with a large C2-C7 sagittal vertical axis (67.5) and O-C2 angle (42°) with a steep (67°), posteriorly oriented odontoid fracture.

Table 3: Results of independent-samples t-tests comparing means for each cervical sagittal measurement between fracture orientation groups.

Direction of fracture	Mean	Standard Deviation	Sig. (2-tailed)
C2-C7 SVA			
OA	29.45	15.73	0.037
OP	40.37	15.77	
C2-C7 angle			
OA	17.92	10.78	0.796
OP	19.07	14.05	
T1 slope			
OA	33.62	10.39	0.148
OP	39.88	13.48	
McGS			
OA	1.11	11.06	0.271
OP	-3.04	10.97	
O-C2 angle			
OA	15.54	9.91	0.009
OP	24.80	10.20	
O-C7 angle			
OA	30.70	12.35	0.008
OP	43.31	13.73	
T1SL-CL			
OA	15.70	9.76	0.191
OP	20.81	12.14	
Age			
OA	67.14	26.92	0.211
OP	78.20	15.36	

OA: Oblique anterior; OP: Oblique posterior; SVA: Sagittal vertical axis; McGS: McGregor's slope

DISCUSSION

Our measures of cervical sagittal balance determined the anterior versus posterior dens fracture angulation (e.g. C2-

C7 SVA, O-C2 angle, and O-C7 angle). A more positive C2-C7 SVA and larger O-C2 and O-C7 angles were associated with posteriorly oriented fractures.

The most severely angulated odontoid fractures were associated with ground-level falls (e.g. significantly greater (40.23°), and falls from a height (35.81°) versus MVAs (18.45°). This finding is an agreement with those of Blizzard *et al.* 2017, in which the authors found that the two most significant measurements in predicting dens fracture angle were anteroposterior sagittal balance and lower cervical disc inclination levels.^[2]

Our linear regression analysis predicted dens fracture angles with an R^2 value of 0.21 using O-C2 angle and age.

CONCLUSION

This study showed that the orientation of the occiput relative to the dens and subaxial cervical spine largely predicted the dens fracture angle and orientation. Posteriorly-oriented odontoid fractures were associated with large C2-C7 SVAs, O-C2 angles, and O-C7 angles, while advanced age and large O-C2 angles were predictors of steep fracture angles [Figure 2].

Declaration of patient consent

Institutional Review Board (IRB) permission obtained for the study.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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