A neurosurgical view of anatomical evaluation of anterior C1–C2 for safer transoral odontoidectomy

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Abstract An anatomical study for evaluation of anterior C1–C2. To provide essential anatomic data for safer transoral odontoidectomy. The surface dimensions of the atlas vertebra and the transoral approach for odontoidectomy have been described in detail. Anterior arcus of C1 must be drilled out to reach odontoid process for transoral odontoidectomy. The thickness of anterior ring of C1 has not been studied before. Sixty, dried adult atlas and 60 axis vertebrae and ten cadaveric craniocervical specimens were measured for the following: (1) bony drilling depth (BDD), the distance from the anterior wall of anterior ring of C1 to anterior wall of odontoid; (2) minimum drilling diameter (MDD), distance of minimum C1 anterior ring removal for odontoid resection on horizontal plane; (3) maximum bony drilling diameter (MBDD), distance of maximum C1 anterior ring removal for odontoid resection on horizontal plane. Lateral border of this diameter is limited by medial borders of the lateral mass; (4) the widest odontoid diameters (WOD) on coronal sections were measured. On 60 atlas and axis vertebrae, the BDD was 7.0 ± 1.2 mm on dry bones, the distance between the medial borders of the lateral mass (MBDD) was 16.1 ± 1.5 mm, and the WOD on coronal sections (WOD) was 9.8 ± 0.8 mm. On

cadavers, the distance between the two edges of C1 anterior ring removal for odontoid resection (MDD) was 10.8 ± 1.1 mm and the WOD on coronal sections (WOD) was 10.1 ± 1.4 mm. An odontoid surgery through transoral approach is safe and feasible. A quantitative understanding of the anterior anatomy of C-1 and C-2 is necessary when considering transoral odontoid resection. In this study the authors define safe zones for anterior atlas and axis.

Keywords Transoral anatomy · Atlas · Axis · Safety zone

Introduction

The transoral approach is an effective surgical procedure for the direct decompression of the ventral cervicomedullary junction. This approach has been recommended by many surgeons for extradural lesions, because it offers decompression between the midclivus and the upper cervical region [4, 5, 8, 10, 17]. The transoral approach for craniospinal malformations was first used by Kanavell and Le Fort in 1918 [11]. Afterward, the transoral approach has been modified by various authors, including Menezes et al. [15, 16], Crockard [2], and Sonntag's group [6] to improve exposure and reduce the complications. The most common indications for this approach are removal of odontoid process for chronic dens dislocation, pseudobasilar invagination caused by rheumatoid arthritis, ventrally located craniocervical tumors, injuries of the upper cervical column and congenital malformations at the skull base [9]. The thickness of anterior ring of C1 and the widest lateral bony borders have not been studied before. The purpose of this study was to provide essential anatomical data for safer transoral odontoidectomy.

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Fig. 1 **a** Superior view of C1. A = bony drilling depth (BDD); B = maximum bony drilling diameter (MBDD). **b** Anterior view of C2. C = the widest odontoid diameters (WOD)

Materials and methods

Sixty, dried adult atlas and 60 axis vertebrae were used to evaluate the osseous anatomy of the atlas and axis were evaluated anatomically. The following dimensions of the atlas and axis were measured bilaterally. All measurements were performed by caliper, accurate to 0.1 mm and were recorded as in millimeters. (1) Bony drilling depth (BDD): the distance from the anterior wall of anterior ring of C1 to anterior wall of odontoid; (2) maximum bony drilling diameter (MBDD): distance of maximum C1 anterior ring removal for odontoid resection on horizontal plane. Lateral border of this diameter is limited by medial borders of the lateral mass; (3) the widest odontoid diameters (WOD) on coronal sections were measured on axis vertebrae (Fig. 1a, b).

Ten cadaveric craniocervical specimens were obtained. Specimens having signs of craniocervical system trauma or disease were excluded. The oral cavity was cleaned and retracted with an oral retractor. The mandible was resected for further exploration of the deep structures. For each cadaver two linear parameters were evaluated morphologically. The following dimensions were measured. (1) The WOD on coronal sections were measured; (2) Minimum drilling diameter (MDD): distance of minimum C1 anterior ring removal for odontoid resection on horizontal plane (Fig. 2).

Mann–Whitney *U* test was used to compare the results. When the *P* value is smaller than 0.05, the test statistics have been statistically significant. Values were expressed as mean $\pm$ standard deviation.

Results

On dry bone measurements, the BDD was 7.0 ± 1.2 mm. MBDD was 16.1 ± 1.5 mm. The WOD on coronal sections was 9.8 ± 0.8 mm. The results of the measurements were presented as mean and standard deviation in Table 1. On cadaveric measurements, the distance between the two

Fig. 2 Anterior view of cadaver. D = the widest odontoid diameters (WOD); E = minimum drilling diameter (MDD)

edges of C1 anterior ring removal for odontoid resection (MDD) was 10.8 ± 1.1 mm, and the WOD on coronal sections (WOD) was 10.1 ± 1.4 mm, listed in Table 2. When the WOD of the cadavers and dry vertebrae were compared, statistically significant difference was not found ($P > 0.05$).

Discussion

Different pathological disorders may produce atlanto-axial translocation with ventral compression of the brain stem or spinal cord. Some of these patients are candidate to the resection of the odontoid process for anterior decompression.

Table 1 Summary of measurements of anatomical landmarks of dried adult cadaveric atlas and axis for anterior odontoidectomy

Parameter	Definition	Mean $\pm$ SD (mm)	Range (mm)
A	Bony drilling depth	7.0 $\pm$ 1.2	4.4–10.4
B	The distance between medial borders of lateral masses (maximum bony drilling diameter)	16.1 $\pm$ 1.5	12.7–20.1
C	The widest odontoid diameter on coronal sections	9.8 $\pm$ 0.8	8.1–11.0

Table 2 Summary of measurements of anatomical landmarks of cadaver's atlas for anterior odontoidectomy

Parameter	Definition	Mean $\pm$ SD (mm)	Range (mm)
D	The widest odontoid diameter on coronal sections	10.1 $\pm$ 1.4	7.5–12.4
E	Anterior ring removal for odontoid resection (minimum drilling diameter)	10.8 $\pm$ 1.1	9.0–14.4

The indications for resection of the odontoid process include nonreducible bony compression of the spinal cord or soft tissue pannus, causing severe ventral compression and resulting in spinal cord contusion with rapidly progressive myelopathy. Transoral approach is a procedure, which has been previously described and used in a clinical setting for odontoid surgery [4, 12–14, 18]. Transoral approach provides a direct route to the surgical field, without any neurovascular manipulation and passing through the oropharynx, without injuring major neurovascular structures.

Congenital anomalies of atlas are observed in 3–5% of patients. They may appear as clefts in the arch, and their location and size vary. Different theories have been proposed to explain congenital defects of the atlas. The patients undergoing odontoidectomy may have congenital anomalies of atlas. Thus, careful preoperative analysis could minimize any inadvertent damage [20].

The study aimed to define the safety zones of the transoral approach. When the resection of the anterior ring of atlas is necessary, the knowledge of anterior ring thickness of atlas provides the surgeon resection depth. Doherty and Heggeness [3], have described that the anterior ring thickness of atlas averaged 6 mm; in addition, Christensen et al. [1] have described that the anterior ring thickness of atlas averaged 6.02 mm. This finding correlates well with that of our study. The distance between the medial borders of the lateral mass is a measure, which keeps the surgeon comfortable to operate on a safe area without any neurovascular complication. Rocha et al. [19]

demonstrated that the distance between the medial borders of the lateral mass averaged 22.9 mm. This result is not concordant with the present study in which the atlas of Turkish people was measured. The cause of concordance may be racial differences. In addition, the authors have used digital analyzing system in the study. This could be affecting the results. Anterior ring removal (MDD) for odontoid resection has not been reported in the English literature up to date. If odontoidectomy is planned, anterior ring removal diameter (MDD) will supply additional information to surgeon to determine the limits of C1 resection. Each patient should be evaluated in detail because of interpersonal differences such as race, age and gender. BDD, MBDD and the WOD should be measured for safe and comfortable working area in a deep plane.

Previously, Tan et al. [21], and Hong et al. [7], have mentioned the distance between C1 anterior tubercle and vertebral artery. The distance between C1 anterior tubercle and vertebral artery was not measured because the medial border of lateral mass should be real lateral drilling border. Maximum vascular drilling diameter could be described as the distance between the midline and the extra osseous segments of vertebral artery. Vertebral artery is situated more lateral to lateral masses at C1–C2 levels. Lateral mass drilling is not necessary in anterior transoral odontoidectomy. Moreover, the drilling of lateral mass leads to C0–C1 joint capsule destruction and further instability and vascular injury. Thus, we recommend limiting our lateral drilling with the medial aspect of lateral masses during anterior odontoidectomy to prevent earlier-mentioned complications. It is not recommended to go far beyond medial aspect of the lateral masses during anterior odontoidectomy.

The safety, feasibility, and reproducibility of the transoral approach procedure need to be described more in detail. Odontoidectomy may be considered one of the most complicated maneuvers for the transoral approach. Because of this, surgeons have to know the odontoid's limits and atlas measures. This cadaver study has been performed to demonstrate the limits of an anterior decompression of the upper cervical cord through an anterior transoral approach. Knowing the limitations prevents complications and provides more encouragement to the surgeon.

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