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The Anterior Endoscopic Transcervical Approach: A Cadaveric Study on Anatomical Challenges and Surgical Limitations in Odontoidectomy

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ABSTRACT

AIM: To investigate the anatomical characteristics, procedural constraints, and technical details of anterior endoscopic transcervical approach (AETCA) through cadaveric dissection.

MATERIAL and METHODS: Nine human cadaver heads, transected at the C6–C7 level and preserved in 10% formalin for no less than 4 weeks, were utilized. A 0° endoscope and surgical drills were used for odontoid removal. The resection extent was determined through volumetric analysis using CT scans performed before and after the procedure. Fluoroscopy was employed for orientation, and volumetric measurements were used to assess the resection outcomes.

RESULTS: Across the specimens, the average resection rate of the dens was 54%. Complete removal was achieved in two cases, subtotal in another two, and partial in five. The use of angled drills yielded significantly greater resection compared to flat-ended variants. No significant vascular or neurological injuries were noted. In seven cases, the resection extended to the odontoid's posterior wall. Challenges included the narrow and elongated operative corridor and difficulty maintaining midline orientation; however, these were addressed with the assistance of a custom-designed tubular trocar.

CONCLUSION: AETCA offers notable benefits, such as reduced risk of postoperative infections, shorter hospitalization, and decreased morbidity and healthcare expenditure. The study underscores the importance of technical expertise and enhanced instrumentation in achieving successful outcomes, particularly for complete odontoid removal while preserving adjacent anatomy. AETCA emerges as a viable and safer alternative for odontoidectomy, enhancing procedural efficiency. These findings contribute to the understanding of anatomical and technical factors relevant to the approach, supporting its clinical adoption and potentially shortening the learning curve.

KEYWORDS: Odontoidectomy, Anterior endoscopic transcervical approach, Cadaveric study, Craniovertebral junction, Surgical techniques

ABBREVIATIONS: AETCA: Anterior endoscopic transcervical approach

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INTRODUCTION

Multiple challenges are associated with surgical approaches to the craniocervical junction when addressing odontoid process pathologies (5,15). The outcome of such procedures is influenced by the distinct anatomical and biomechanical properties of this region. In addition to the established transoral and transcervical approaches, endoscopic techniques have also been employed in recent years.

The anterior endoscopic transcervical approach (AETCA) offers certain benefits, including its extrapharyngeal trajectory, which lowers the risk of bacterial contamination at the surgical site, as well as postoperative morbidity and hospital stay duration (3). Despite the inherent technical challenges of this method, AETCA appears to provide an appropriate surgical corridor for managing odontoid process pathologies. In this study, our objective was to assess the anatomical features of AETCA and explore its potential surgical limitations.

MATERIAL and METHODS

This study was conducted in the Microsurgical Neuroanatomy Laboratory of Cerrahpasa Medical Faculty and received approval from the Institutional Ethics Committee (Approval No: 83045809-604.01.02). A total of nine human cadaver heads, sectioned at the C6–C7 level, were utilized. All specimens have been preserved in a 10% formalin solution for a minimum duration of 4 weeks. For the resection procedures, a 5-mm diameter, 0° angled, 306-mm-long endoscope (Storz) was employed. A modified lumbar spinal endoscopy trocar was also used during the procedures.

Bone resections were conducted using different drill configurations: for the first five specimens, a straight attachment and straight-tip burr motor (Faro F632, Faro USA, Burlingame, CA, USA) operating at 30,000 rpm was used. For the remaining four specimens, a 30° angled burr motor (Medtronic, Midas Legend) with AT10 and ATT12 attachments, running at 75,000 rpm and equipped with a 2-mm burr tip, was utilized.

Anatomy of the Craniovertebral Junction

The vascular supply of this region is provided by the vertebral artery (VA) and the meningeal branches of the internal carotid artery. The third segment of the VA (V3) begins after the C2 level, extending laterally toward the transverse foramen of C1. After traversing this foramen, the artery reaches the posterior atlanto-occipital membrane and subsequently the dura mater. At this juncture, the fourth segment (V4) of the VA commences. Notably, anterior fixation procedures in this region carry a risk of complications due to possible screw penetration into these arterial structures.

Surgical Technique

The dissection began at the C5–C6 level with the cadaver positioned neutrally, using fluoroscopic assistance and a standard Smith–Robinson incision made from the right anterior cervical region. A skin incision was made at this level, and under fluoroscopic control, alignment with the odontoid process was achieved to establish the optimal trajectory. A trocar was introduced through the incision, and the endoscope was advanced via the trocar, allowing visualization of the anterior C2–C3 disc space and the anteroinferior portion of the C2 vertebral body. Following the opening of the platysma, dissection proceeded medially to the sternocleidomastoid muscle. The carotid sheath was retracted laterally, while the trachea was retracted medially, continuing in a superomedial direction. In the upper cervical region, after reaching the anterior surfaces of the vertebral bodies, the prevertebral muscles were retracted. The endoscopic trocar was then repositioned at approximately a 30° angle at the level of the odontoid process. Resection of the odontoid process was carried out using an endoscope and a drill inserted through the trocar (Figure 1).

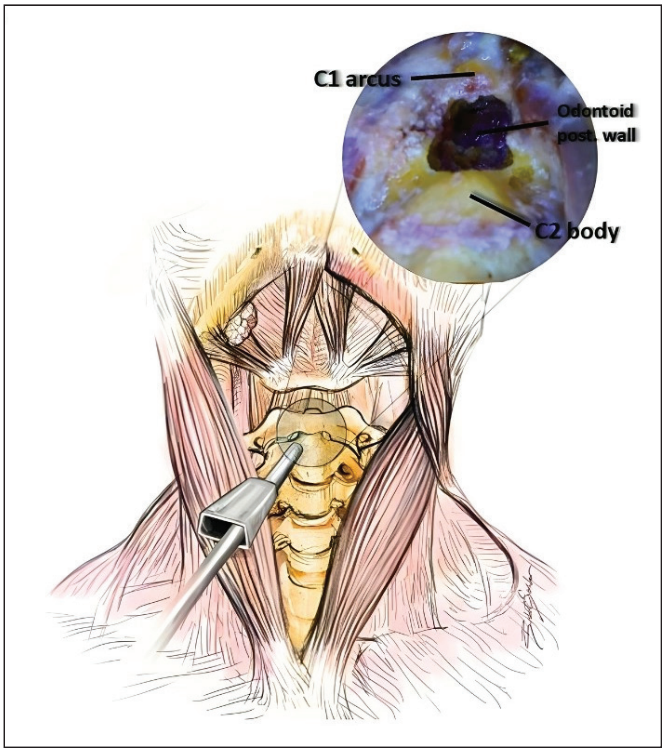

Figure 1: Diagram illustrating the surgical technique for resecting the odontoid process. The procedure starts with a right anterior cervical Smith–Robinson incision at the C5–C6 level, guided by fluoroscopy. The carotid sheath is retracted laterally and the trachea medially to allow access to the cervical spine. The prevertebral muscles are retracted to expose the anterior surface of the vertebral bodies. An endoscopic trocar is positioned at roughly a 30° angle at the odontoid process level, enabling resection with a drill passed through the trocar. The inset shows the endoscopic view, identifying key anatomical landmarks such as the C1 arch, the posterior wall of the odontoid process, and the C2 body. Figure 1 presents a basic anterior perspective of the surgical approach, created by a medical illustrator. The trocar is inserted through a skin incision at the C5–C6 level and advanced toward the odontoid process under alignment guidance. An example of the endoscopic view is shown in the upper right corner.

Radiological Evaluation

Once the prevertebral region was accessed during the procedure, the position of the odontoid process was identified using fluoroscopy in both sagittal and coronal planes, guided by the endoscopic trocar. Three-dimensional (3D) CT images centered on the craniovertebral junction were obtained for all specimens before and after the resection. Using the Radiology Workstation (Carestream Solutions®), the volume of resected odontoid tissue and its proportion relative to the total odontoid volume were calculated. The quantification of the resected volume was based on pre- and post-resection 3D CT imaging, and the percentage of resection was determined for each specimen.

RESULTS

The resection data from the nine cadaveric specimens are presented in Table I. On average, 54% of the dens volume was resected. In the first five specimens, where a flat-end drill tip was employed, the mean volume of resection was 28.5%. In contrast, the use of an angled drill in the remaining four specimens resulted in a markedly higher resection percentage, averaging 85.8%. These volumetric values were calculated by comparing pre- and post-resection 3D CT scans using the Radiology Workstation software, which allowed for accurate measurement of the removed odontoid volume in relation to the original anatomical structure (Table II). In seven specimens, it was possible to resect the anterior arch of C1 and reach the posterior cortical wall of the odontoid process. In cases where near-complete resection of the odontoid was achieved, no significant arterial, venous, or neural injuries were identified in any of the cadavers. Following resection, 3D CT imaging focused on the craniovertebral junction was obtained for all specimens (Figure 2).

DISCUSSION

The dens axis represents an anatomically critical area, where surgical intervention carries significant risk due to its proximity to vital anatomical structures (7,10,11). Furthermore, a thorough understanding of the complex anatomy of this region—difficult to access because of its deep location and limited surgical corridors—is essential for evaluating different surgical techniques and selecting the most appropriate method for individual patients (3,19,21). While transoral (transpharyngeal) approaches offer a broad surgical view and access for ventral decompression, particularly in cases of basilar invagination, they have been associated with notable postoperative morbidity in some instances (1,2,4,6,9). In addition, when supplementary procedures such as Le Fort osteotomy or mandibulotomy are required to enlarge the surgical field, the overall morbidity increases and hospital stays become longer (12,14). These concerns have prompted the exploration of alternative approaches to the traditional transoral technique. Advances in endoscopic technology have played a key role in this development. The AETCA was introduced as a means to avoid the complications linked to traditional transoral and endonasal pathways in surgeries addressing the dens, particularly in the context of platybasia.

Common complications associated with transpharyngeal approaches—both transoral and endonasal—include direct exposure to oral and nasal flora, extended intubation periods,

Table I: Drill and Resection Data of All Specimens

Specimen No	Drill type	Resected volume ratio (%)	Resected of C1 anterior arcus	Extending posterior odontoid wall
1	Flat-end	17.8	No	No
2	Flat-end	16.5	No	No
3	Flat-end	35.7	Yes	Yes
4	Flat-end	41.1	Yes	Yes
5	Flat-end	31.4	Yes	Yes
6	Angled	57.8	Yes	Yes
7	Angled	85.7	Yes	Yes
8	Angled	100.0	Yes	Yes
9	Angled	100.0	Yes	Yes

Table II: Resection Data According to Drill Type

Drill type	Resection ratio (%)	Resection of C1 anterior arcus (%)	Extending posterior odontoid wall (%)
Flat-end group	28.5	40	40
Angled group	85.8	100	100

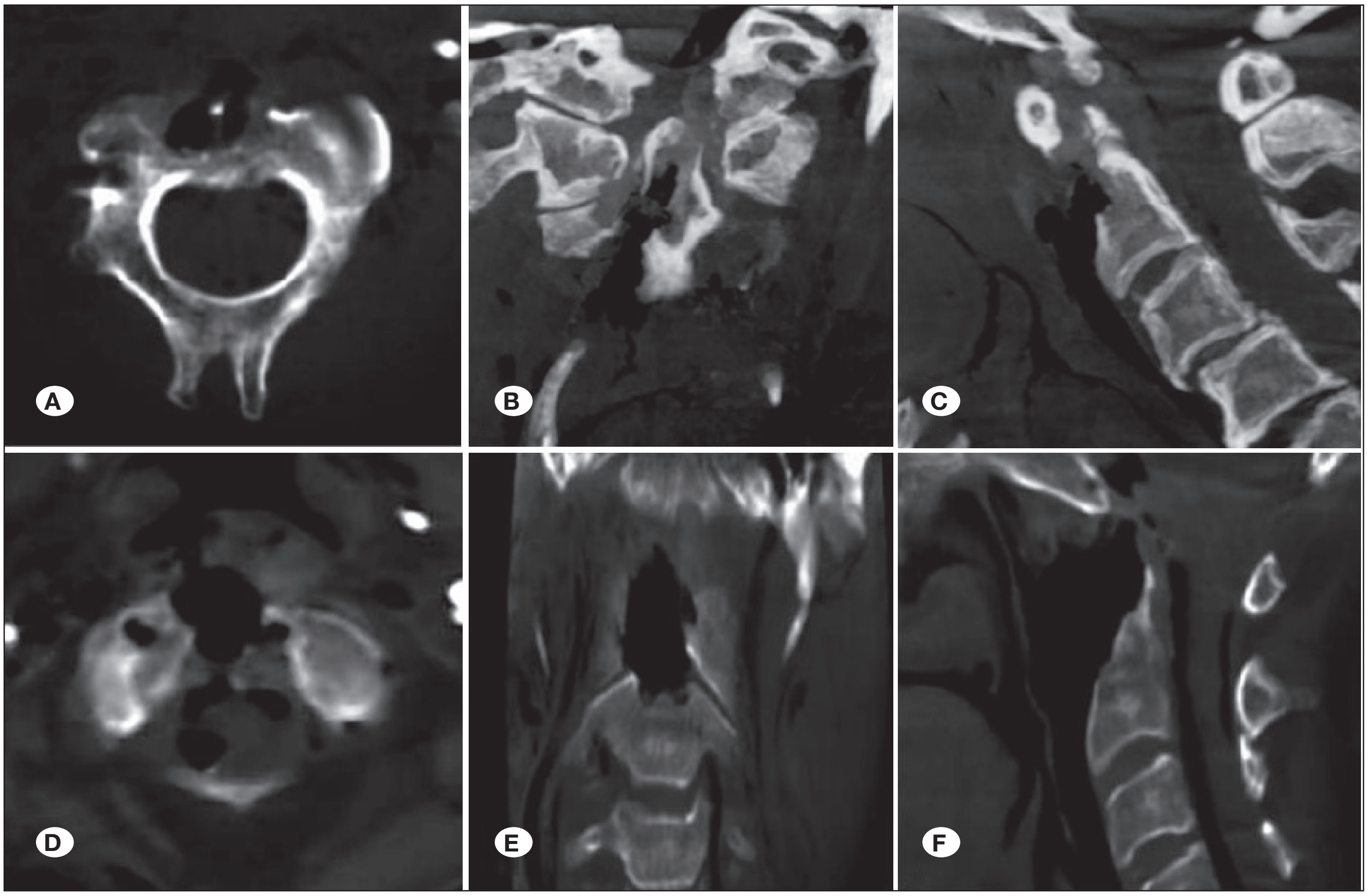

Figure 2: Three-dimensional CT images of the craniovertebral junction from cadaver specimens following odontoid process resection. **A–C)** Axial, coronal, and sagittal views displaying partial resection of the posterior wall of the odontoid cortex and the anterior arch of C1. **D–F)** Additional axial, coronal, and sagittal views demonstrating the odontoid process and adjacent anatomical structures after complete resection.

the need for tracheostomy in certain cases, reliance on nasogastric tube feeding postoperatively, cosmetic concerns particularly in transmandibular approaches, and prolonged hospitalizations. To address and potentially eliminate these issues, the AETCA was developed (5,13,15,19,20,22). The primary advantage of AETCA over endoscopic transoral and endonasal techniques lies in the fact that the pharyngeal mucosa remains intact, significantly reducing the risk of bacterial contamination and subsequent infection. Since this approach avoids mucosal incision, unlike the transoral route, it minimizes the likelihood of postoperative infection. As there is no clinical studies on AETCA currently available in the literature, these anticipated benefits can only be evaluated through cadaveric studies such as this one. Moreover, minimizing infection risk and removing the need for postoperative nasogastric tube placement can lead to reduced hospital stays, thereby decreasing morbidity and lowering overall healthcare costs. In a study by Dogan et al., the authors noted that posterior endoscopic procedures resulted in shorter hospital stays and were more cost-effective than anterior approaches (8). Consequently, patients undergoing AETCA experience no delay in postoperative feeding, eliminating the need for further interventions such as PEG placement. It has also been demonstrated that AETCA allows for earlier extubation and reduced hospitalization time, thereby lowering associated morbidities and care expenses (18).

There are several challenges when applying the AETCA technique compared to transoral and endonasal approaches. The primary anatomical difficulties include the length and narrowness of the surgical corridor and the challenges of accurately identifying the midline (18). To achieve precise midline localization and complete resection in clinical practice, technical aids such as neuronavigation, intraoperative CT, or fluoroscopy should be available (14,16,17). In our dissections, fluoroscopy in sagittal and coronal planes was used for surgical orientation once the prevertebral area was reached. The drawback of the long surgical corridor is lessened by using a trocar, which allows retraction without tissue damage within the corridor. Although the use of a specialized trocar is necessary, familiarity with anterior dissection at the C5–C6 level is important when comparing this technique to other endoscopic retropharyngeal approaches (16-18). A specially designed tubular trocar is employed for AETCA. Its tubular shape offers a 360° safe working space, and during our dissections, no major arterial, venous, or esophageal–tracheal injuries were noted in any cadavers. However, since three or more surgical instruments (such as the endoscope, drill, and aspirator) are often used simultaneously within the trocar, surgical manipulation and the surgeon's movements can become relatively more difficult. This may prolong the surgical time and potentially influence the success of the resection. Additionally, trocar movement during surgery could cause microtrauma in the neck region of patients, though there is currently no data in the literature addressing this issue, and further clinical studies are required.

In odontoidectomy performed via AETCA, the adequacy of technical equipment is the primary factor influencing surgical success. The type of drill used affected the dens resection rates observed in cadavers. Clinical series in the literature generally employed angled endoscopes (25–30°), but except for one study, all have used non-angled drills (22). In our study, a 0° endoscope was used, while bone resection was carried out with drills of different angles. The use of drills with varying angles also affected the odontoid resection rates in our dissections. With a flat-end drill, reaching the posterior wall of the odontoid was not possible. When comparing resection amounts between the two drill types, cadavers treated with angled drills showed significantly higher resection rates.

The second factor contributing to the AETCA's success is the accumulation of surgical experience (21). Two major challenges to gaining proficiency in endoscopic surgery are the steep learning curve and the absence of depth perception due to two-dimensional imaging (22). Our study also showed the impact of increased surgical experience on resection outcomes. In cadavers where flat-end drills were used, resection rates improved from 17.8% to 31.4% over time, while in those with angled drills, the rate increased from 57.8% to 100%.

Other approaches, such as transoral and endoscopic endonasal techniques, have the advantage of better access to the posterior section of the odontoid (13,15). In AETCA, accessing the posterior section of the dens is more challenging because of the angle of the endoscope relative to the dens axis. In odontoidectomies—especially those performed on patients with basilar invagination—surgical success depends on the adequacy of brainstem decompression, with the goal of achieving sufficient decompression. Moreover, surgical outcomes reported in the literature have not been evaluated volumetrically, nor have specific criteria been established to define the extent of resection. Our study measured the extent of resection volumetrically and reported it as a percentage of the original odontoid volume. This method allowed for an objective comparison of different surgical instruments and techniques employed during AETCA.

The first limitation of our study is that the AETCA technique was mainly evaluated in terms of its anatomical features, limitations, and characteristics. However, because this was a cadaveric study, were unable to evaluate surgical success or the risks of complications. The second limitation is the absence of the cadavers' bodies, which allowed us to adjust the head position during dissection as needed—an advantage not possible in live patients. It is also important to note that accessing the odontoid region via AETCA may be difficult or impossible in patients with broad chests, severe obesity, or marked thoracic kyphosis. The third limitation is that our technical setup required resection of the C1 arch to achieve complete odontoidectomy. With increased surgical experience, advancements in endoscopic and drilling techniques, and improved equipment, it may become possible to preserve the C1 arch. Further anatomical and surgical studies are needed to refine and enhance the technique.

CONCLUSION

AETCA offers benefits including a reduced risk of postoperative infection, shorter hospital stays, prevention of potential morbidities, and lower healthcare costs. However, challenges such as a long surgical corridor and difficulties with midline orientation are associated with the technique. Nevertheless, success can be achieved by utilizing specially designed trocars, angled drills, and supplementary imaging methods. This cadaver study, which focused on the technical and anatomical aspects of AETCA, aims to shorten the learning curve and help surgeons gain experience prior to performing odontoidectomy on patients. Future clinical studies are needed to evaluate patient outcomes following AETCA.

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Declarations

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Availability of data and materials: The datasets generated and/or analyzed during the current study are available from the corresponding author by reasonable request.

Disclosure: The authors declare no competing interests.

AUTHORSHIP CONTRIBUTION

Study conception and design: OY, SA

Data collection: OY, SA, GZS

Analysis and interpretation of results: OY, SA, GZS

Draft manuscript preparation: OY, SA, AEA

Critical revision of the article: SA, AEA

Other (study supervision, fundings, materials, etc...): SA, AEA

All authors (OY, SA, AEA,GZS) reviewed the results and approved the final version of the manuscript.

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