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SURGERY

Endoscopic Transnasal Odontoidectomy: A Novel Technique in Orthopedic Surgery

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Abstract

Purpose Over the past decade, a minimally invasive technique to address upper cervical spine pathology has been executed successfully within ENT and neurosurgical communities. One indication for this endoscopic transnasal surgery is to remove the odontoid process of C2.

Methods We aim to provide a detailed description of the current state of endoscopic endonasal odontoidectomy (ETO) techniques through a systematic literature review. We also report the clinical course of a patient who underwent an ETO with involvement of an orthopedic spinal surgeon. It is our hope that by highlighting the feasibility and positive outcomes of this approach, it may propagate more broadly through the spine community.

Results A 61-year-old male presented to clinic with complaints of neck pain that radiated into the right arm. He had a remote history of closed head injury as a professional boxer, as well as previous ACDF from C4 to C7. On exam, the patient was myelopathic with diffuse 4/5 weakness in all extremities. Imaging revealed a Type-1 odontoid fracture non-union and significant stenosis at the C1 level, with only 7.7 mm available for the cord. After conferring with an interdisciplinary team, the patient was indicated for C1 laminectomy with posterior spinal fusion of C1–C2 and endoscopic transnasal odontoidectomy.

At 5-month follow-up, the patient has reported improved gait mechanics, absence of RUE paresthesias, and improved RUE strength.

Conclusions ETO is a viable, safe alternative to previously used methods of odontoid resection. As familiarity with the procedure increases throughout the medical field, further research should determine the most effective methods of ameliorating known complications.

Keywords Endoscopic · Odontoid process · Endonasal · Transnasal · Cervical spine decompression · Odontoidectomy

Introduction

Compression of the ventral brainstem at the craniocervical junction can be due to numerous etiologies, any of which can adversely affect the patient's quality of life and survival. The critical surrounding neurovascular anatomy complicates the surgical treatment. In cases of fixed bony compression, odontoidectomy is sometimes necessary to achieve adequate decompression [1–6].

Over the past half century, transoral odontoidectomy combined with posterior fixation has been the standard procedure to treat these conditions [2–4, 6–22]. While several procedural modifications can extend the pharyngeal exposure rostrally, they are associated with significant potential morbidities such as prolonged intubation, dysphagia (with resultant tracheostomy/gastrostomy), suboptimal cosmesis, nasal regurgitation, and hypernasal speech [3, 6, 8, 10, 15–18, 23–27]. Due to contamination by oral flora, the transoral approach was thought to be associated with a higher risk of infection, but documented infection rates are actually between 0.6 and 1.9% [5, 6, 10, 14, 16, 18, 28].

In 2005, Kassam et al. proposed an endoscopic endonasal approach as a more direct route to the craniocervical junction. This approach avoids palatal or pharyngeal incisions, tongue

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retraction, and a midline glossotomy or mandibulotomy, thereby improving the safety and feasibility of odontoidectomy [6, 9, 13, 16, 25, 29–31]. Consequently, patients rapidly resume oral feeding and have minimal risk to their airway [21]. By limiting the incision rostral to the palatal plane, the surgeon avoids the laterally based pharyngeal plexus to the constrictor muscles, decreasing the risk of postoperative dysphagia [26]. Moreover, the muscles that form the palatopharyngeal sphincter at Passavant's ridge are not disrupted, thereby eliminating velopharyngeal insufficiency and the resultant nasal regurgitation and hypernasal speech.

While the rarity of the procedure's indications limit reported cases, the orthopedic surgery literature rarely mentions this approach outside of indications secondary to rheumatoid arthritis [11, 13, 15, 24]. We will present the detailed clinical case of a patient who underwent ETO concurrently with a posterior C1–C2 decompression and fusion. Additionally, we aim to provide a detailed description of the current state of endoscopic transnasal/endonasal odontoidectomy (ETO) techniques through a systematic literature review. By highlighting the feasibility and positive outcomes, we hope to propagate this approach more broadly through the spine community.

Methods

Systematic Review

A systematic literature review was performed utilizing the PubMed database as the primary conduit for accessing existing literature. However, the "Primo" search function available through the Baylor University Medical Center Health Sciences Library was also used, allowing the authors to access additional sources through the CIHAHL Complete database, the Cochrane Central Register of Systematic Reviews, the Cochrane Central Register of Controlled Trials, and the Ovid MEDLINE databases. On January 2, 2019, the primary author (S.N.) conducted a PubMed database search with the initial algorithm: "Odontoid Process/abnormalities" + "Odontoid Process/Injuries" + "Odontoid Process/pathology" + "Odontoid Process/surgery". This use of those MeSH terms yielded 1423 articles.

Through the sequential addition of more specific Medical Subject Heading (MeSH) terms such as: "minimally invasive surgical procedures"/"endoscopy" + "nasal cavity"/"transnasal"/"endonasal" a yield of 66 total articles were ultimately compiled. When adding the MeSH filter "orthopedic" to this collection, the number of articles decreased to four, so this filter was not included.

Inclusion/Exclusion Criteria

We imposed no restriction on publication status. Our review excluded animal studies and was limited in scope to articles published within the past 10 years, except when mining bibliographies for relevant studies. Due to the presumed novelty of this procedure and the limited amount of published data, we elected not to impose a restriction on the number of patients presented in case series. Exclusion criteria included duplicate articles, foreign language studies, radiologic studies, and irrelevant studies. After application of the inclusion and exclusion criteria, full-text versions of the included articles were then obtained. The bibliographies of the full-text articles were examined for any additional articles not found in the original search.

Clinical Review

Patient Characteristics and Initial Presentation

A 61-year-old male, formerly a professional boxer and race car driver, presented to the outpatient spine surgery clinic with complaints of neck pain that radiated to the right arm. He also complained of right-hand weakness, decreased sensation in the fifth digit of the right hand, and ataxia. These symptoms were present for nearly a year but had become acutely worse in the preceding 2 months. As a child, the patient was in a racing accident in which he sustained traumatic brain and spine injuries. The patient had ongoing tremors since then and underwent anterior cervical discectomy and fusion (ACDF) of levels C4–C7. He denied any recent injury or antecedent trauma that aggravated the pain.

On exam, the patient had decreased motion of the cervical spine as well as moderate discomfort at the extremes of cervical motion. The patient had 4/5 motor strength in all muscle groups of the right upper extremity. The patient had hyperreflexia in both the upper and lower extremities. A CT scan of the cervical spine demonstrated a well-healed ACDF of the C4-C5, C5-C6, and C6-C7 levels. There was central spinal canal stenosis at the C1–C2 level with a prominent periodondoid calcific focus, but no evidence of atlantoaxial subluxation on the static images. There was also a grade I spondylolisthesis at C7-T1.

Dynamic radiographs did not demonstrate any instability at C1–C2, nor at the degenerative spondylolisthesis of C7-T1. An MRI demonstrated significant central canal stenosis at the C1 level, with an AP spinal canal diameter of 7.7 mm. There was mild myelomalacia of the cervical cord at this level. Multidisciplinary review determined that the calcific mass posterior to the odontoid process was not consistent with calcium pyrophosphate deposition (CPPD) disease. The patient was diagnosed with C1–C2 stenosis with progressive myeloradiculopathy.

Based on the patient's exam and imaging findings, the orthopedic spine surgeon (M.B.) decided to proceed with an initial posterior C1–C2 decompression/fusion, concurrently followed by transnasal endoscopic resection of the ventral bony compressive lesion in cooperation with an ENT surgeon experienced in transnasal surgery. Imaging confirmed that the craniocervical junction could be sufficiently approached to the body of C2 and that the internal carotid artery was not serpiginous in its course.

Relevant Anatomy

The endoscopic endonasal approach utilizes a trajectory through the anterior nasal aperture, the nasal vestibule, and their posterior communication with the nasopharynx, the cloanae. The roof of the nasal cavity is formed by the nasal, frontal, ethmoid, and sphenoid bones, while the floor is formed by the palatine process of the maxilla and the horizontal plate of the palatine bone. Medially, a perpendicular plate of the ethmoid bone, vomer, and septal cartilage join to form the primary elements of the nasal septum. To allow for a wider working corridor and thus prevent damage to surrounding structures, the posterior and inferior 1/3rd of the nasal septum turbinates are frequently resected in a flap based on the vascular distribution of the sphenopalatine artery; if that does not provide adequate exposure, further septectomy of the middle turbinate can be performed. In general, the composition of the flap includes the choanae, the base of the septum, anterior middle turbinate, and 1 cm below the nasal roof. The lateral wall of the nasal cavity is comprised of the superior, middle, and inferior conchae of the ethmoid bone, as well as several foramina allowing continuity with sinuses, air cells, and neurovascular structures.

The anterior arch of C1 and the odontoid process are found dorsal to the posterior wall of the nasopharynx. The lower 2/3rds of the nasal cavity are composed of mucous membrane, through which an incision is made to access the bony craniovertebral junction. The Eustachian tubes represent the lateral limits of this approach and can also serve to reorient a surgeon to the midline posterior wall of the nasopharynx. The torus tubarius and the Fossa of Rosenmüeller are also identified bilaterally. Deep to the mucosa are the insertions of the longus coli and longus capitis muscles, the former attached to the anterior tubercle of the atlas and the latter to the lower extent of the clivus. Once the odontoid process is adequately visualized, it must be freed from any ligamentous attachments, such as the alar (inserting on the medial faces of the occipital condyles) or apical ligaments (attached to the clivus), though care should be made to avoid sectioning these stabilizing structures.

Preoperative Planning

Careful preoperative review of radiographic images, including MRI and CT, is critical when considering the endonasal transnasal approach. In particular, outlining the palatine line, a line along the plane of the hard palate towards the craniovertebral junction on the sagittal computed tomography images, can help determine the feasibility of the endonasal approach by generalizing the inferior limit of the surgical working corridor. Compressive lesions above the palatine line are readily accessed in this fashion, though extension below the line is only a relative contraindication.

After endotracheal tube intubation, the patient is placed in the supine position with the head secured in a Mayfield 3-pin fixation system. The head is secured in a neutral position, as flexion or extension may worsen spinal cord pathology. Antibiotic prophylaxis is given.

Useful instruments and adjuvant modalities include

- 4-mm diameter, 18-cm length high-definition endoscope with irrigation sheath

- (0–30° recommended)

- Stereotactic neuronavigation system
- Mayfield 3-tong headrest
- Neuromonitoring of somatosensory evoked potentials, motor evoked potentials, and bilateral brainstem auditory evoked potentials

Operating room layout

- Two surgeon, binostril access

- Both surgeons are typically on the patient's right side
- The endoscope is inserted through the right nostril
- Dissection instruments and drill are inserted through the left nostril

- The patient's abdomen and right thigh are prepped within the surgical field

- The clival dura Is more vulnerable to iatrogenic durotomy than the dura of the craniovertebral junction, so careful excision of the inferior clivus with eggshell technique is recommended.
- If intraoperative CSF leak is present and the defect is small, an autologous infraumbilical fat graft and fascia lata onlay graft can plug the durotomy. Larger defects that are unable to be adequately repaired may require CSF diversion for 48-72 hours

Surgical Technique

The patient was brought to the operating suite and underwent general anesthesia with oral endotracheal intubation. Spinal cord monitoring leads were placed and Mayfield tongs were applied to the patient's head, at which point he was placed in a prone position and appropriately secured.

- Posterior C1-C2 Decompression/Fusion

A midline incision was made just distal to the inion and extended 5 cm caudally. The deep fascia was incised in plane with the skin incision. The paracervical musculature was reflected laterally and fluoroscopy confirmed the level.

Attention was then turned towards the placement of bilateral C1 lateral mass screws. On each side, the C2 nerve roots were sacrificed to facilitate better exposure of the C1–C2 facet joints. At C2, pars interarticularis screws were placed. To prepare the fusion site, the articular cartilage of the C1–C2 facet joints was removed, and a cutting burr was used to decorticate the endplates. Into each C1–C2 facet joint, a Cornerstone (Medtronic, Memphis, TN) anterior cervical allograft was inserted. A 3.5-mm titanium rod was fixed to the C1 and C2 screws on each side and a cross-link was placed between the C1 screw heads. C1 laminectomy was then performed, and the bone was morselized and redirected along the dorsal aspect of the C1–C2 facet joints. Final visualization with the C-arm showed the graft and fixation to be in good position. One gram of vancomycin powder was rubbed into the soft tissues and a medium-sized Hemovac drain was placed deep to the fascial layer. The paracervical musculature was closed in multiple layers with interrupted 0 Vicryl suture, and the deep fascia was closed with an interrupted no. 1 Vicryl suture. Following wound closure, the patient remained in the Mayfield tongs, and he was carefully turned to the supine position for the endonasal portion of the procedure.

- Endonasal Odontoidectomy

The nasal cavity was prepared with Afrin-soaked cottonoids. After the Stryker intraoperative stereotaxic navigation system (Stryker, Kalamazoo, MI) was appropriately calibrated, the endoscopic endonasal approach was performed by an experienced ENT surgeon (A.B.). The entire procedure was performed with a 0-degree endoscope. Mild septal deviations are typically of little consequence and the patient did not require septoplasty. Examination of the nasopharynx revealed no lesions and normal Eustachian tube orifices (Figs. 1 and 2). The inferior turbinates were next lateralized and a posterior septectomy removed approximately 2 cm of the posterior septal bone and mucosa. Using an extended-tip needle-point Bovie cautery, an inverted U-shaped pharyngeal incision was made through the mucosa and constrictor muscular layer down to the pharyngobasilar fascia (Fig. 3). This inferiorly based flap was sharply dissected off of the fascia. Lateral cuts were made in the Fossa of Rosenmuller, taking care not to injure the Eustachian tubes, and this flap was reflected inferiorly behind the soft palate. Next, the pharyngobasilar fascia was incised using Bovie cautery and the prevertebral tissues were removed using a combination of cautery and 0-degree Thru-Cut forceps. Dissection was taken down through the longus capitis muscles laterally. This exposed the anterior arch of C1 to the medial aspect of the lateral tubercles (Fig. 4). Dissection was then directed superiorly removing the soft tissue at the base of the clivus, providing excellent exposure to the craniocervical junction. The anatomy and exposure was confirmed with intraoperative stereotaxis.

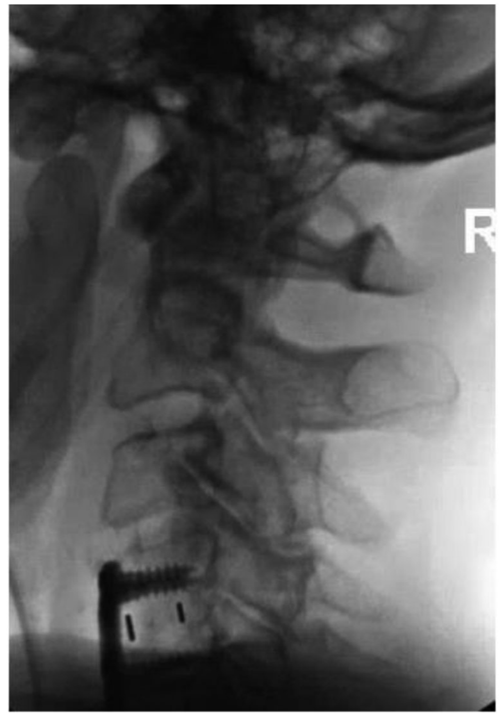


Fig. 1 Preoperative lateral radiograph demonstrating superior aspect of previous ACDF and ventral C1-C2 compressive calcification

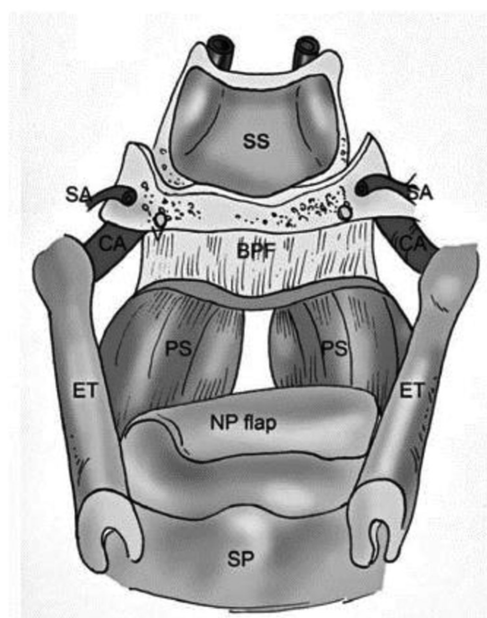


Fig. 2 Illustration demonstrating the surgical field and its exact limits before elevation of the nasopharyngeal flap. (NP: nasopharyngeal flap; SS: sphenoid sinus; SA: sphenopalatine artery; CA: carotid artery; BPF: pharyngobasilar fascia; PS: paraspinal muscles; ET: Eustachian tube; SP: soft palate; FM: foramen magnum; OC: occipital condyle; D: dens; C1: atlas; C2: axis) (Image used with permission of Dr. Grammatica)

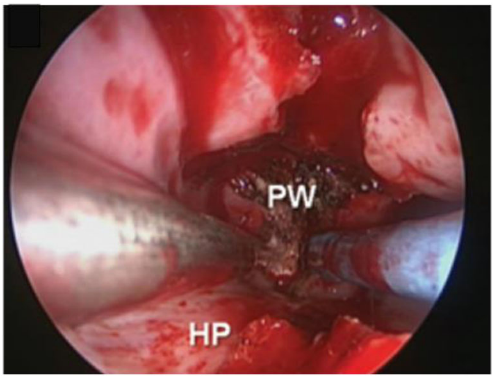


Fig. 3 Intraoperative endoscopic photographs of ETO. A midline incision is made in the posterior pharyngeal wall (PW). (HP: Hard palate) (Image used with permission from Dr. Liu, who has copyright ownership)

A drill removed the anterior arch of C1. Next, the preexisting fibrosis posterior to the arch was removed, and the odontoid process was revealed (Fig. 5). A 4-mm cutting burr was used to remove a 14-mm section of the anterior odontoid (Fig. 6). Curettes and pituitary rongeurs were used to remove the remaining posterior shell of the odontoid as well as the calcific nodules that were located within the ligaments ventral to the dura (Fig. 7). These ligaments were found to be deformed and thickened, so they were excised. The entire os odontoid was removed, as were the bony spicules surrounding the os and the ligaments to the level of the dura. Great care was taken to ensure the dura was not violated. The dura was pulsating at the conclusion of the procedure (Fig. 8).

In addition to fluoroscopic imaging, sufficient excision of bone and complete decompression was confirmed by the placement of Omnipaque dye into the nasopharynx and the resection cavity (Fig. 9). Hemostasis was confirmed and there was no evidence of CSF leak. Closure was performed by placing Surgicel and Surgifoam into the resection cavity. The pharyngeal flap was then translocated from the oropharynx and repositioned to reconstruct the posterior nasopharynx and was secured with fibrin glue. Doyle splints were placed in

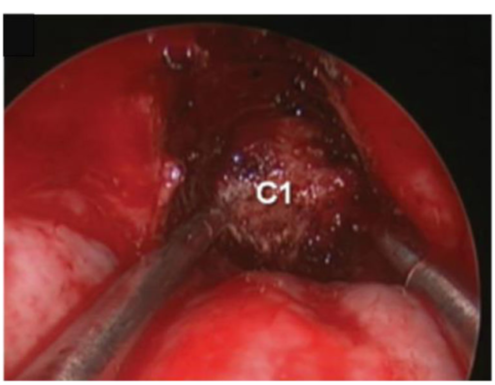


Fig. 4: Intraoperative endoscopic photographs of ETO. The anterior arch of C1 is exposed (Image used with permission from Dr. Liu, who has copyright ownership)

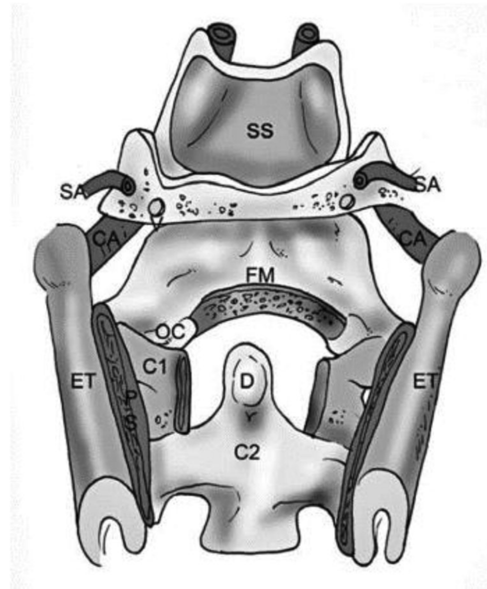


Fig. 5 Illustration demonstrating the surgical field and its exact limits after exposure of the C1–C2 articulation and removal of anterior arch of C1. (NP: nasopharyngeal flap; SS: sphenoid sinus; SA: sphenopalatine artery; CA: carotid artery; BPF: pharyngobasilar fascia; PS: paraspinal muscles; ET: Eustachian tube; SP: soft palate; FM: foramen magnum; OC: occipital condyle; D: dens; C1: atlas; C2: axis) (Image used with permission of Dr. Grammatica)

both nasal cavities and secured anteriorly. No feeding tube was placed.

The patient was awakened from anesthesia and extubated without difficulty. A Miami J collar was placed and he was transferred the ICU for critical care monitoring. The patient tolerated the procedure well, and there were no untoward intraoperative events. Total blood loss for the anterior and posterior portions of the case was 450 mL and 15 0mL, respectively.

Follow-Up

Immediately following the procedure, the patient was taken to the intensive care unit for close neurological monitoring. He

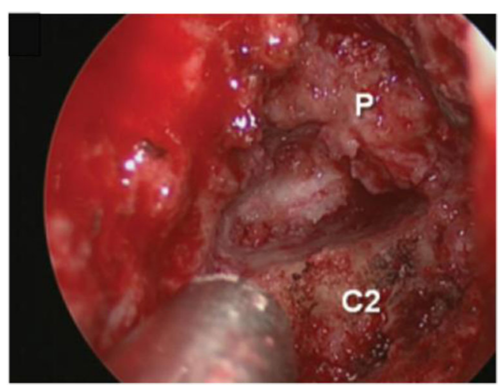


Fig. 6 Intraoperative endoscopic photographs of ETO. The arch of C1 has been removed, exposing the odontoid process. The odontoid process is removed with use of a burr. (Image used with permission from Dr. Liu, who has copyright ownership)

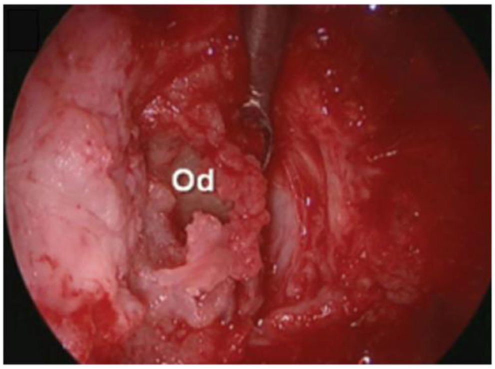


Fig. 7 Intraoperative endoscopic photographs of ETO. Curettes and pituitary rongeurs are used to remove the remaining posterior shell of the odontoid (Od: odontoid process) (Image used with permission from Dr. Liu, who has copyright ownership)

developed no new neurologic deficits and was started on a clear liquid diet on postoperative day (POD) no. 1, and subsequently gradually advanced to a puree diet. He was subsequently transferred to the floor, mobilized, and discharged home on POD no. 4.

Two weeks postoperatively, the patient noted improved strength in his right upper extremity in all muscle groups of the bilateral upper extremities. At this point, he was tolerating a regular diet and had no problems with speech or swallowing. At 6 weeks, he was feeling well with no nasopharyngeal symptoms (e.g., Eustachian tube dysfunction) and reported that his gait had improved, as had the paresthesias in his right upper extremity. The cervical brace was discontinued 3 months postoperatively.

Unfortunately, the patient was involved in a motor vehicle collision at the 8-month postoperative mark and was evaluated by the emergency room staff at his local hospital. No acute findings were noted at that time. At follow-up, the patient endorsed decreased sensation to the bilateral hands and paresthesias, with the right hand worse than the left. Review of plain radiographs and CT of the cervical spine did not reveal any fractures, or any loosening or broken hardware (Fig.10). His fixation and fusion remained intact. The patient was

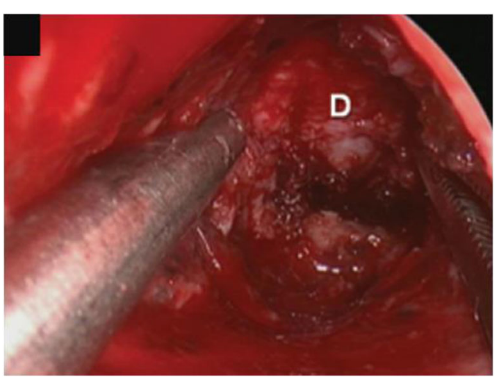


Fig. 8 Intraoperative endoscopic photographs of ETO. The dural sac (D) is evaluated for integrity and complete decompression (Image used with permission from Dr. Liu, who has copyright ownership)

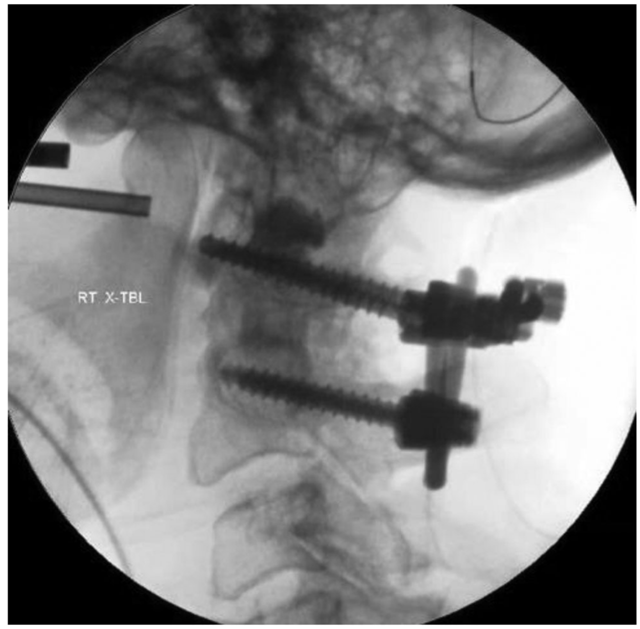


Fig. 9 Intraoperative fluoroscopic image demonstrating completed posterior spinal fusion of C1 and C2, as well as odontoidectomy. Notably, the calcific nidus of the ventral and superior aspect of the dens is no longer visualized

referred for an MRI to evaluate the spinal cord for injury or stenosis. This MRI, performed 9 months postoperatively, demonstrated a well-decompressed spinal cord between the foramen magnum and C7.

Discussion

Compression of the brainstem occurs due to a number of processes that affect the craniocervical junction, including congenital abnormalities, neoplasms, infections, and traumatic lesions. Surgical removal of the odontoid process is sometimes necessary to adequately decompress the brainstem. Odontoidectomy has evolved as investigations and innovation surrounding surgical techniques progress.[2, 3, 9, 32–34]

Transnasal, transoral, and transcervical approaches are utilized in instances when access to the odontoid is necessary to treat ventral compression of the brainstem.[2, 3, 9, 15, 32–35] (Fig. 11). The original method for odontoidectomy was the transoral route, but continued success, decreased complications, and evolution of transnasal techniques have led to an increase in utilization of ETO [9, 23, 34–37].

The transnasal approach for odontoidectomy offers significant advantages over the transoral technique. One of the primary advantages of ETO is the direct and sufficient exposure of the entire dens. The transoral approach inherently limits superior exposure, constraining access to the most cranial aspects of the odontoid process. In attempts to improve rostral visualization, extensile measures, such as maxillotomy,

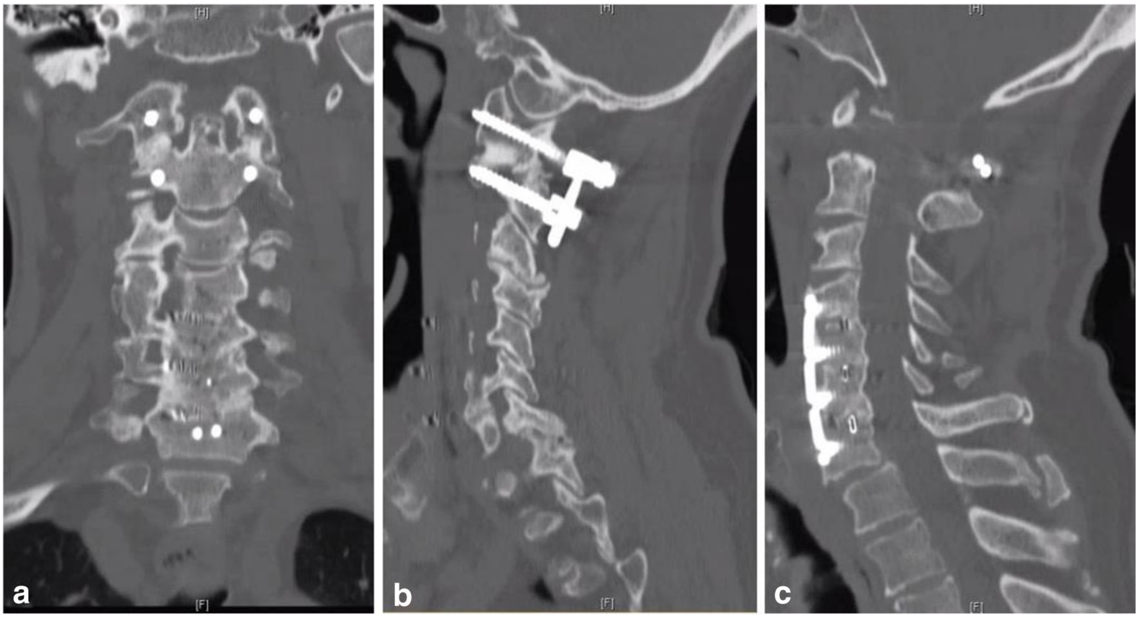


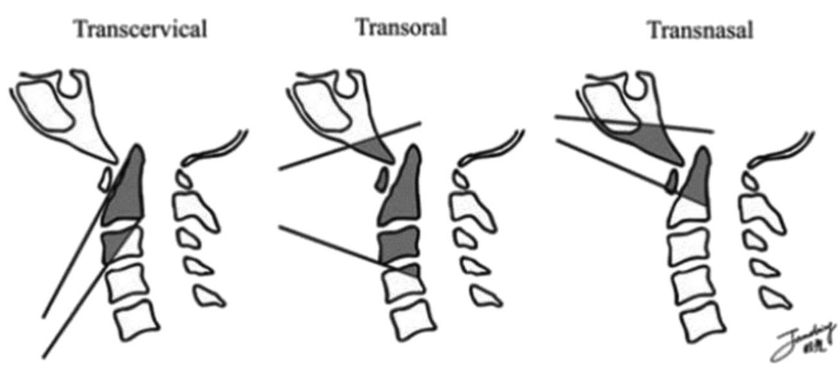
Fig. 10 **a** Postoperative coronal CT image demonstrating excision of odontoid process and well placed C1–C2 instrumentation (lateral mass and pars interarticularis screws, respectively), as well as partially visualized previous C4-C7 ACDF construct. **b** Postoperative parasagittal CT image demonstrating consolidation of the fusion between the C1–C2 facet joints. **c** Postoperative midsagittal CT image with evidence of superior odontoidectomy and a well-decompressed spinal cord between the foramen magnum and C7

palatomy, midline glossotomy, and mandibulotomy, may be performed, but are associated with increased surgical morbidity and potential complications [9, 19, 35]. When patients are selected appropriately, ETO provides direct access from the body of C2, superiorly to the base of the clivus. Furthermore, endoscopy provides a panoramic surgical view, and the surgical exposure can be widened to provide sufficient access, even in cases with severe platybasia and high dens position [32].

ETO also imposes a minimal impact on the airway. It is straightforward and does not include disruption of normal tissues of the tongue, palate, or oropharynx. Consequently, the oral and oropharyngeal airway is not affected, obviating the need for prolonged intubation. Postoperatively, ETO has consistently shown to significantly decrease the rate of postoperative tracheostomy, as well as a shorten the average hospital stay, when compared to the transoral approach [6, 19]. The elevated rates of tracheostomy following the transoral approach are most commonly due to prolonged intubation and post-surgical edema of collateral tissues involved in the approach, which causes occlusion of the upper airway [3, 36]. The transnasal approach allows a more prompt resumption of oral intake and decreased risk of aspiration and suppression of the cough reflex [3, 36, 38].

In addition, patients undergoing ETO have an immediate resumption of swallowing function. Passavant's ridge represents the functional sphincter formed by the palatopharyngeus muscle integrating into the superior constrictor muscle. Transoral approaches implicitly mandate a disruption of this sphincter mechanism. Additionally, midline palatotomy divides the palatal elevators and foreshortens the soft palate. Because of these superimposed issues, the velopharynx cannot close efficiently. This results in nasal regurgitation and hypernasal speech, which may not improve with speech therapy. Furthermore, ETO does not disrupt the oropharyngeal vagal plexus, keeping the neuromuscular

Fig. 11 Schematic drawing demonstrating the different trajectories associated with each approach, as well as the feasible extent of odontoidectomy (Image used with permission of Dr. Wu)



function of the middle and superior constrictors intact [32]. Patients are typically started on a clear liquid diet on POD no. 1 but are gradually advanced to a puree and finally a soft diet over the following 2 weeks.

ETO is not without its limitations. The craniocaudal trajectory of the transnasal approach makes accessing structures inferior to the nasopalatine line difficult [15, 32]. Multiple maneuvers, like posterior nasal spine removal, have been reported to circumvent this issue. This adaptation, in particular, significantly increases the caudal limit of visualization from a transnasal approach [39]. Furthermore, use of angled instruments and endoscopes can improve visualization rostral to the nasopalatine line [3, 23, 40]. The exposure is limited laterally by the lacerum and paraclival segments of the internal carotid artery as well as the hypoglossal nerves, whose proximity to the field confers risk when approaching this area [38]. A well-documented complication of the transnasal approach is cerebrospinal fluid (CSF) leak, so although they are notoriously difficult to repair, the use of autologous fat grafts and fibrin glue has been used with some success.[2, 3, 6, 9, 40]

As with any new technique, there is a learning curve associated with adoption of ETO [18]. The average surgical time of ETO was 356.4 min in one study, whereas the average time with the transoral approach was only 141 minutes in another [18, 37]. Though surgical length will vary among practitioners, with experience and further refinements to instrumentation and navigation, operative times will likely decrease.

There is very little consensus on the optimal timing of posterior stabilization in the setting of odontoidectomy, regardless of approach utilized [3, 40]. It is understood that one of the risks associated with odontoidectomy is secondary craniocervical instability, especially in cases where the arch of C1 is resected for more optimal visualization of the odontoid process [38, 40]. Most commonly, stabilization is achieved by either posterior C1–C2 or occipito-cervical fusion. Depending on the patient's age, pathoanatomy, and the absence of preoperative occipitocervical instability, certain physicians may elect to not perform a posterior fusion [23, 33]. Another consideration that may become increasingly relevant in the future of ETO surgery relates to a technical element of the procedure. While preservation of the anterior arch of C1 has been shown to limit C1–C2 subluxation, due in part to the capsular ligaments, paraspinal muscles, and ligamentum flavum that restrain excessive C1–C2 movement, it is commonly sacrificed to improve visualization [34, 41]. Iacoangeli et al. conducted a study on seven patients who underwent endoscopic endonasal odontoidectomy with preservation of the C1 arch. Of the seven patients, there were two patients that underwent anterior fusion, and five cases in which patients did not receive fusion. There were no radiologic signs of instability in either cohort [33]. While timing of posterior fusion may vary, more extensive research may circumvent the issue altogether, as we evaluate the necessity of posterior stabilization in patients who undergo ETO with an intact anterior arch of C1.

Our case report provides additional support to the emerging literature that supports the use of ETO as a less morbid approach to ventral compressive lesions at the craniocervical junction [11, 31, 42]

Conclusion

Endoscopic transnasal odontoidectomy (ETO) is a viable, safe alternative to previously used methods of odontoid resection in the treatment of brainstem and upper cervical compression of various etiologies. As familiarity with the procedure increases, the most effective methods of ameliorating the known complications of the operation will likely emerge. In cases where the anterior arch of C1 is preserved, additional study should explore the need for posterior stabilization. Surgical experience and improved instrumentation will further increase the acceptability and utility of this innovative approach to these important, yet infrequently encountered, cases.

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Authors' Contributions

Drs. Nimmons, Rizkalla, Bhatki, Berchuck, and Mr. Volkmer all made substantial contributions to the conception and design of this study, as well as acquisition of data. Dr. Nimmons and Dr. Berchuck performed critical analysis and interpretation of data. All members of the team worked to draft the article. Dr. Berchuck, Dr. Nimmons, and Dr. Bhatki revised it critically for important intellectual content. All the members gave final approval of the version to be published.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the study.

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