Original Article

Transcervical, retropharyngeal odontoidectomy – Anatomical considerations

ABSTRACT

Context: Anterior craniocervical junction lesions have always been a challenge for neurosurgeons. Presenting with lower cranial nerve dysfunction and symptoms of brainstem compression, decompression is often required. While posterior approaches offer indirect ventral brainstem decompression, direct decompression via odontoidectomy is necessary when they fail. The transoral and endoscopic endonasal approaches have been explored but come with their own limitations and risks. A novel retropharyngeal approach to the cervical spine has shown promising results with reduced complications.

Aims: This study aims to explore the feasibility and potential advantages of the anterior retropharyngeal approach for accessing the odontoid process.

Methods and Surgical Technique: To investigate the anatomical aspects of the anterior retropharyngeal approach, a paramedian skin incision was performed below the submandibular gland on two cadaveric specimens. The subcutaneous tissue followed by the platysma is dissected, and the superficial fascial layer is opened. The plane between the vascular sheath laterally and the pharyngeal structures medially is entered below the branching point of the facial vein and internal jugular vein. After reaching the prevertebral plane, further dissection cranially is done in a blunt fashion below the superior pharyngeal nerve and artery. Various anatomical aspects were highlighted during this approach.

Results: The anterior, submandibular retropharyngeal approach to the cervical spine was performed successfully on two cadavers highlighting relevant anatomical structures, including the carotid artery and the glossopharyngeal, hypoglossal, and vagus nerves. This approach offered wide exposure, avoidance of oropharyngeal contamination, and potential benefit in repairing cerebrospinal fluid fistulas.

Conclusions: For accessing the craniocervical junction, the anterior retropharyngeal approach is a viable technique that offers many advantages. However, when employing this approach, surgeons must have adequate anatomical knowledge and technical proficiency to ensure better outcomes. Further studies are needed to enhance our anatomical variations understanding and reduce intraoperative risks.

Keywords: Basilar invagination, odontoidectomy, submandibular retropharyngeal, transcervical approach, ventral decompression

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INTRODUCTION

For nearly a century, lesions in the anterior craniocervical junction have created a dilemma for neurosurgeons. Lower cranial nerve dysfunction and signs of brainstem or spinal cord compression are the usual clinical presentations of such lesions.[1] Anterior brainstem compression can be caused by various pathologies and conditions such as basilar invagination,[2] odontoid fracture nonunion,[3] rheumatic, infectious, and neoplastic processes.[4-6] To avoid progressive myelopathy and relieve symptoms, such cases often necessitate direct decompression.[6,7] Indirect

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ventral brainstem decompression can be done by posterior approaches such as posterior C1–C2 distraction and fixation by which neural decompression and atlantoaxial stability can be achieved in some circumstances without anterior access.[8] If posterior approaches fail, odontoidectomy is a well-established and effective strategy for decompressing the anterior craniovertebral junction (CVJ).[9]

Several approaches have been studied to achieve the most effective decompression with minimal surgical morbidity. Traversing the oral cavity via the traditional transoral transpharyngeal approach is the most studied approach.[2,10-16] This direct approach carries potential complications that are mostly related to the access route.[4,5,17,18] For example, tongue edema, splitting of the soft palate, the need for a nasogastric tube,[19] the need for tracheotomy,[20,21] velopharyngeal incontinence,[20,21] and nasal regurgitation due to late fibrotic soft palate contracture are all reported complications.[10] Likewise, this approach increases the risk of oral cavity bacterial contamination. Furthermore, undesirable cosmetic outcomes are expected in situations where the transmandibular route[9,22-24] or LeFort osteotomies[25-27] are used for wider exposure.

Another approach that gained popularity with increasing case reports in the literature, is the endoscopic endonasal odontoid decompression, which emerged as an extension of the endoscopic endonasal techniques usually used for the treatment of skull base pathologies.[28-31] This approach carries the advantage of avoiding the need for a tracheostomy or a soft palate-splitting incision. Moreover, it carries a lesser risk of bacterial contamination as the defect created by this approach is above the contact level of the soft palate with the posterior pharynx where bacteria are lesser in number and virulence than those in the oropharynx.[32] Additionally, it permits earlier postoperative feeding and early extubation.[33] On the other hand, some authors have documented an elevated risk of cerebrospinal fluid (CSF) leak and meningitis related to the endoscopic endonasal approach.[34] Furthermore, Shriver *et al*. in their study found that the increased incidence of tracheostomy after the transoral route is the only complication that significantly differs between transoral and endonasal approaches.[35] Therefore, while both the transoral and endonasal approaches are effective, it is worth exploring less invasive methods with a potentially improved complication profile and cosmetic outcomes.

Another option to reach the odontoid process is through the direct lateral trans-C1 approach, a variation of the established far lateral approach designed for addressing pathology ventrolateral to the brainstem and craniocervical junction. This adapted technique is typically used for lateral lesions without notable ventral or dorsal extension, serving as a viable option when the standard far lateral approach is deemed overly extensive.[36]

A novel approach has been increasingly adopted, in which a routine Smith-Robinson approach to the cervical spine is utilized to establish a retropharyngeal tubular odontoidectomy. As shown in Figure 1, a beveled tubular retractor system is then used to access C2 and the odontoid process without the need for extensive retropharyngeal dissection. Many case series and cadaveric anatomical studies have consistently demonstrated the viability, efficacy, and benefits of this approach over alternative methods.[25,37-42] This approach avoids incision of the pharyngeal mucosa and consequently its related complications. Additionally, spine surgeons are generally familiar with the anatomy and corridor of the anterior cervical spine approach. With that background, this article reviews pertinent anatomical aspects based on cadaveric dissections and aims to demonstrate the feasibility of odontoidectomy through a transcervical, retropharyngeal approach. Further important anatomic considerations are discussed based on the literature.

METHODS AND SURGICAL TECHNIQUE

Following a paramedian skin incision just below the submandibular gland on two cadaveric specimens, the subcutaneous tissue followed by the platysma is dissected and the superficial fascial layer is opened. Figure 2 shows the anatomical structures of relevance. The plane between the vascular sheath laterally and the pharyngeal structures medially is entered below the branching point of the fascial vein and internal jugular vein. The superior pharyngeal artery and vein cross this plane. Attempts should be made to preserve these structures, which is typically possible. Once the prevertebral plane is reached, further dissection

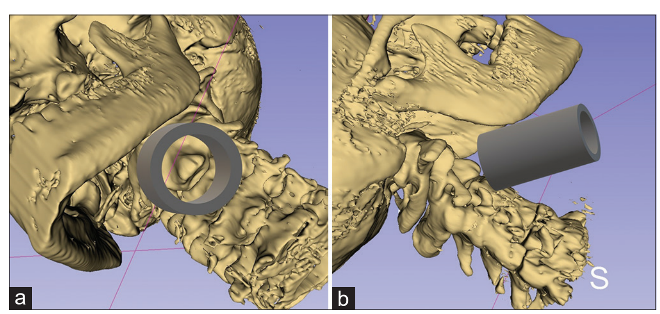

Figure 1: Three-dimensional volume rendered model of a cervical spine specimen. (a and b) schematically shows the placement and orientation of the tubular retractor system to access C2 and the odontoid process

cranially is done in a blunt fashion below the superior pharyngeal nerve and artery, as shown in Figure 3. The anterior surface of the odontoid is then exposed, as shown in Figure 4.

RESULTS

The anterior, submandibular retropharyngeal approach to the cervical spine was successfully completed in two cadavers. A cadaveric image and computed tomography (CT) reconstruction from one of the specimens dissected with a right-sided approach is shown in Figure 5. In the other cadaver, a left-sided approach was used, which is shown in Figures 6 and 7. A cadaveric cross section is shown in Figure 8, highlighting relevant anatomy in this region, including the carotid artery, as well as the glossopharyngeal, hypoglossal, and vagus nerves.

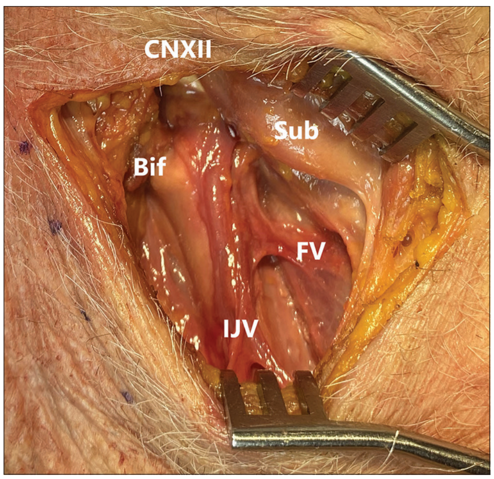

Figure 2: Cadaver specimen, right-sided submandibular approach to the high cervical spine. Bif Carotid bifurcation, CNXII - Hypoglossal nerve, FV - Facial vein, IJV - Internal jugular vein, Sub - Submandibular gland. White line indicates the level of the mandible

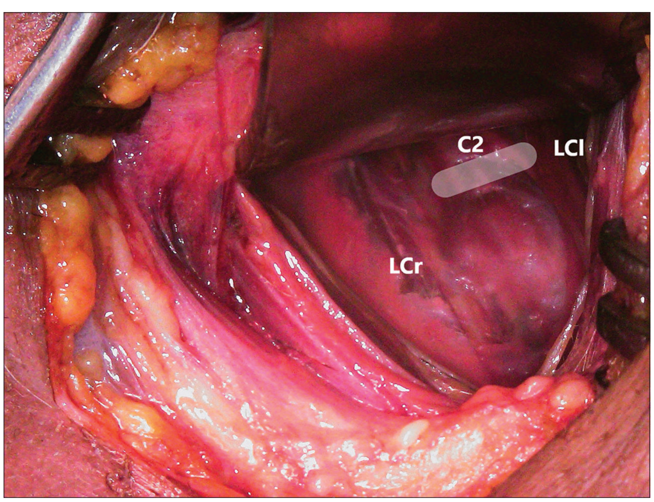

Figure 4: Cadaveric specimen, right-sided submandibular approach. C2 - Inferior margin C2 vertebral body; LCl - Longus colli left, LCr - Longus colli right

DISCUSSION

A variety of strategies have been used to approach ventral craniocervical junction lesions, and efforts have been made to improve the operative view and minimize the operative time and potential postoperative complications. This study adds to growing evidence demonstrating that anterior retropharyngeal approach to the upper cervical spine is a viable alternative to transoral surgery, enabling direct anterior access to C1 and C2. Additionally, this approach provides the flexibility for extension to the lower cervical spine.[25,37,39,43,44]

In 2005, Fong and DuPlessis *et al*. developed a retropharyngeal exposure technique for accessing the odontoid process similar to the approach used for anterior transarticular screws. While it avoids traversing the oral mucosa and benefits from the protective anatomy of the craniocervical junction, this approach carries the risk of stretch injury to the superior laryngeal nerve, hypoglossal nerve, and marginal branch of the mandibular nerve.[43] Therefore, understanding regional anatomy is crucial to optimizing the safety profile of the procedure.[45-47]

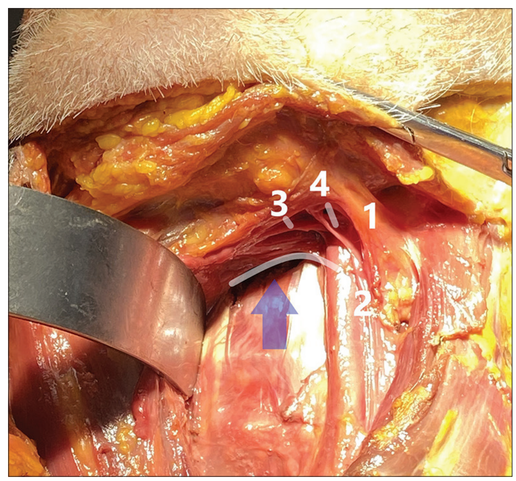

Figure 3: Cadaveric specimen left side. 1 - Cervical fascia, 2 - Vascular sheath blue arrow, 3 - Superior thyroid artery, 4 - Superior laryngeal nerve

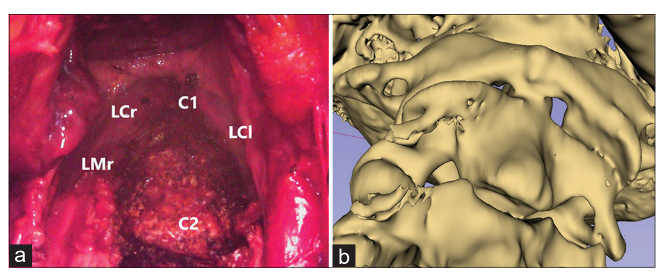

Figure 5: Right submandibular approach, (a) cadaveric specimen, (b) three-dimensional reconstruction of corresponding computed tomography scan. C1 - Anterior tubercle of C1, C2 - Inferior margin of the C2 vertebral body, LCl - Longus colli left, LCr - Longus colli right, LMr - Lateral mass of C2 right

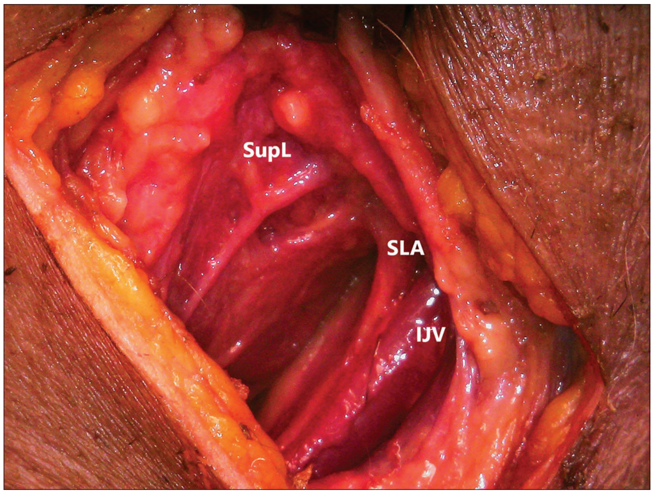

Figure 6: Cadaveric specimen, left-sided submandibular approach. IJV - Internal jugular vein, SLA - Superior laryngeal artery, SupL - Superior laryngeal nerve

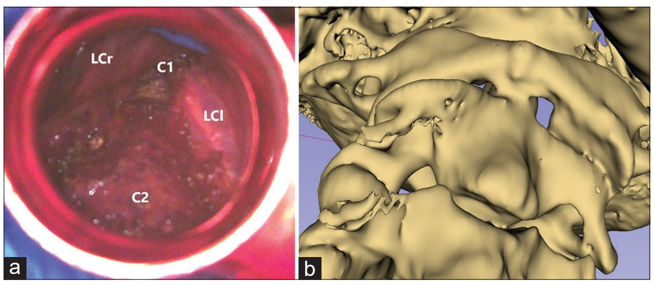

Figure 7: Left submandibular approach, (a) cadaveric specimen through tubular retractor, (b) three-dimensional reconstruction of corresponding computed tomography scan. C1 - Anterior tubercle of C1, C2 - Inferior margin of the C2 vertebral body, LCl - Longus colli left, LCr - Longus colli right

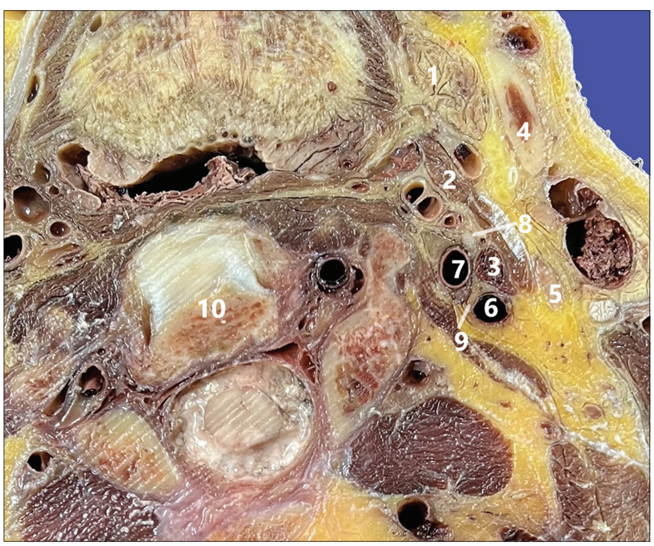

Figure 8: Axial cross section through cadaveric specimen. 1 - Submandibular gland, 2 - Digastric muscle, 3 - Stylohyoid muscle, 4 - Mandible, 5 - Hypoglossal nerve, 6 - Internal jugular vein, 7 - Carotid artery, 8 - Glossopharyngeal nerve, 9 - Vagal nerve, 10 - C2/3-disc space

Park *et al*. found that by opening the lower part of the submandibular gland capsule and dissecting below the gland through this opening, the facial nerve can be spared as it lies in a superior and more superficial position. They also found that injury to the hypoglossal nerve is another possible complication of this approach that leads to unilateral tongue palsy and deviation, but dissecting inferior to the digastric muscle can avoid excessive traction on this nerve.[48]

Deep to the loop of the superior thyroid artery, lies the proximal portions of the superior laryngeal nerve and its branches. Injury to this nerve leads to cricothyroid muscle palsy and sensory deficit in the laryngeal mucosal membrane. Although it may be challenging to diagnose unilateral nerve injuries, which are often asymptomatic, this problem may carry considerable importance for some patients. Another common problem often encountered in high cervical approaches is dysphagia, which is often transient but can persist for months.[48] In a review conducted by Natsis *et al*. about the origin of the superior thyroid artery, numerous anatomical variations were found, which make this artery a poor landmark for locating the superior laryngeal nerve.[49] An anatomical report done by Park *et al*. concluded that wide dissection of the fascial planes may help decrease the injury risk as less force is required for retraction leading to a lower risk of stretch-related injury.[48] Additionally, recurrent laryngeal nerve injury is more frequent in the lower cervical approach than in upper approach, as in the latter, the surgical corridor is above the thyroid cartilage.[50]

A study by Iwanaga *et al*. in 2021 aimed to locate the pharyngeal branches by dissecting cranial nerves IX and X and the sympathetic trunk in the neck of 10 cadavers. The study revealed that the pharyngeal branches originating from the glossopharyngeal, vagus nerves, as well as the superior cervical ganglion, enter the posterior pharyngeal wall at the C2–C4 levels approximately 10 mm medial to the greater horn of the hyoid bone. It was observed that all pharyngeal branches were situated anterior to the alar fascia. Additionally, based on the anatomical findings, it was determined that the vagus nerve branches to the pharyngeal muscles entered at the C3/C4 vertebral levels. This anatomical knowledge may aid in reducing the occurrence of nerve injury following cervical spine surgery.[51]

Although arterial injury during anterior cervical approach is extremely rare,[52,53] it is crucial to preoperatively understand the possible arterial anatomical variations, as such injuries can lead to serious consequences. Bruneau *et al*. studied the anatomy of 500 vertebral arteries (VAs) on different imaging modalities. According to their anatomic report, failure to identify a tortuous course of the VA during an anterior approach may result in unintentional damage.[45] Furthermore, an increased incidence of VA anomalies in both the extraosseous and intraosseous regions is seen in patients with osseous anomalies at the CVJ. To mitigate the risk of intraoperative VA injury, and understand the anomalous VA anatomy before surgery, a three-dimensional CT angiography can be performed preoperatively.[47]

Ultimately, more studies are needed to enhance our understanding of anatomy. Future studies must focus on anatomical variation investigation to reduce intraoperative injury risk. By advancing our anatomical knowledge and implementing innovative surgical techniques, we can further refine approaches to the craniocervical junction and minimize potential complications.

CONCLUSIONS

The anterior retropharyngeal approach is a viable technique for reaching the craniocervical junction. This approach offers advantages such as wide exposure and avoidance of oropharyngeal contamination. It also provides a potentially safer environment for managing CSF fistulas. However, due to complex region anatomy, this approach requires a high level of technical skill and good understanding of the anatomical structures to ensure successful outcomes. Cadaveric dissection is a potentially useful exercise for surgeons who are unfamiliar with this approach to familiarize.

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Conflicts of interest

There are no conflicts of interest.

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