Original Article

Real-time ultrasound guidance in the endoscopic endonasal resection of a retro-odontoid pannus: Technical note and case illustration

ABSTRACT

Background and Objectives: Odontoidectomy is a surgical procedure indicated in the setting of various pathologies, with the main goal of decompressing the ventral brain stem and spinal cord as a result of irreducible compression at the craniovertebral junction. The endoscopic endonasal approach has been increasingly used as an alternative to the transoral approach as it provides a straightforward, panoramic, and direct approach to the odontoid process. In addition, intraoperative ultrasound (US) guidance is a technique that can optimize safety and surgical outcomes in this context. It is used as an adjunct to neuronavigation and provides intraoperative confirmation of decompression of craniovertebral junction structures in real time. The authors aim to present the use and safe application of real-time intraoperative US guidance during endonasal endoscopic resection of a retro-odontoid pannus.

Methods: A retrospective chart review of a single case was performed and presented herein as a case report and narrated operative video.

Results: A minimally invasive US transducer was used intraoperatively to guide the resection of a retro-odontoid pannus and confirm spinal cord decompression in real time. Postoperative examination of the patient revealed immediate neurological improvement.

Conclusions: Intraoperative ultrasonography is a well described and useful modality in neurosurgery. However, the use of intraoperative US guidance during endonasal endoscopic approaches to the craniovertebral junction has not been previously described. As demonstrated in this technical note, the authors show that this imaging modality can be added to the ever-evolving armamentarium of neurosurgeons to safely guide the decompression of neural structures within the craniocervical junction with good surgical outcomes.

Keywords: Compressive myelopathy, expanded endonasal approach, intraoperative ultrasound, odontoid process, skull base surgery

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INTRODUCTION

The craniocervical junction (CVJ) is a distinct osseoligamentous region with complex anatomic morphology. The CVJ contains important neurovascular structures and stabilizing ligaments. Movement at the CVJ is responsible for 50% of motion in both neck extension, flexion, and axial rotation.[1,2]

Rheumatoid arthritis (RA) induced retro-odontoid pannus is one of the most prevalent acquired diseases in the CVJ.[3] Pannus progression can compromise osseoligamentous

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stability, leading to cervicomedullary compression.[4,5] Stabilization with or without decompression is the standard of care for this pathology.

Anterior approaches to the CVJ provide direct access to the odontoid process and source of compression, and the endoscopic endonasal approach (EEA) has been demonstrated to be a viable technique.[6-9] Surgical technique requires resection of the pannus and removal of fibrous tissue to adequately decompress the spinal cord, while minimizing the risk of cerebral spinal fluid (CSF) leak or inadverdent spinal cord injury during resection. In this manuscript, we aim to describe the benefits of intraoperative ultrasound (US) to guide safe and effective spinal cord decompression in patients with myelopathy secondary to a retro-odontoid pannus.

METHODS

The authors retrospectively reviewed a case of one patient who underwent an EEA for retro-odontoid pannus resection and spinal cord decompression (guided by intraoperative US), followed by posterior occipitocervical instrumented fusion. The patient's informed consent was obtained for surgical intervention. Data were collected within the guidelines of the institution's IRB-approved retrospective database, along with the patient's signed consent to use case information and associated video footage. The surgical technique and the information related to the US are described, followed by the case report. Case review and reports followed the instructions of CARE guidelines.[10]

The intraoperative endonasal US was performed using the BK Medical Bk 5000 US System with the N20P6 Minimally Invasive 6 mm × 7 mm Transducer.

The images from the surgery and the US were gathered and edited using a video editing software.

Surgical technique

The patient's head is rigidly fixed in a Mayfield three-pin head holder. The head is slightly flexed and rotated to the right. Neuronavigation is calibrated to help with anatomical orientation. An endoscopic endonasal binostril approach to the nasopharynx was utilized, as previously described.[8] Once the choana is reached, the endoscope is directed toward the base of the odontoid. The eustachian tubes and Rosenmuller fossa are identified, and two vertical incisions are performed in the posterior oropharynx medial to the eustachian tubes. Another horizontal incision is performed by connecting the upper limb of the vertical incisions. The mucosa and muscle are reflected caudally. A subperiosteal exposure of the anterior C1 arch is performed, confirmed with neuronavigation. The C1 arch is drilled, starting at midline and extended bilaterally until the arch begins to curve laterally and posteriorly. The dens is then identified by its "pearl-like" appearance. It is then drilled out starting at its center. During this process, a thin arch of bone consisting of the superior and lateral borders of the dens is preserved. Ligamentous attachments are released at the apex of the dens, and Kerrison Rongeurs are then used to remove the remaining posterior cortical bone.

Once the bony elements are resected, the US probe (bk5000; BK Medical, 6 mm × 7 mm minimally invasive transducer-N20P6) is then introduced into the surgical corridor to characterize the depth of the pannus and the remaining degree of spinal cord compression. Based on dynamic intraoperative feedback, the surgeon is able to dissect and remove the pannus and abnormal ligamentous structures. The US probe may be used intermittently to confirm adequate spinal cord decompression and safely guide removal of the inflammatory tissue. The intraoperative real-time confirmation of spinal cord decompression is based on the identification of the free-flowing CSF column anterior and posterior to the spinal cord.

Once spinal cord decompression is achieved, hemostasis is obtained using a combination of cautery and hemostatic agents, and the harvested myomucosal flap is reflected to cover the surgical site. The Valsalva maneuver can be performed to confirm no CSF leak has been encountered.

Case description

A 72-year-old male presented to the emergency department with 4 weeks of progressive neck pain associated with upper-extremity weakness, decreased grip strength, gait ataxia, and loss of manual dexterity. On physical examination, the patient exhibited 4/5 on muscle strength for biceps and handgrip bilaterally. Hoffman's reflex was positive bilaterally, and there was sustained clonus in the upper extremities bilaterally with thenar atrophy. The patient had a medical history significant for RA, type 2 diabetes mellitus, essential hypertension, gastroesophageal reflux disease, and heart failure with decreased ejection fraction. Pertinent surgical history included previous C3–C7 anterior cervical discectomy and fusion, spinal cord stimulator implantation, as well as previous thoracic and lumbar decompressions [Figure 1 – patient timeline].

Diagnostic computed tomography (CT) imaging revealed a calcified retro-odontoid mass causing spinal cord compression at the CVJ and C7-T1 stenosis. The pannus was associated with degenerative and erosive changes at the medial atlantoaxial joint, measuring 9.4 mm × 31.1 mm

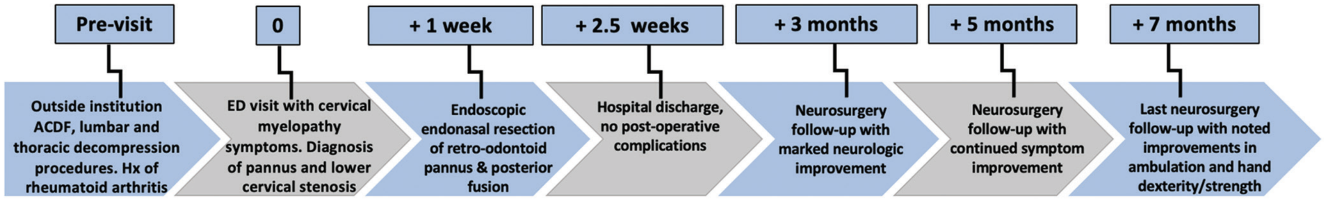

Figure 1: Timeline of significant events and outcomes in the patient's care

in the anteroposterior and craniocaudal dimensions, respectively [Figure 2]. As there was ambiguity surrounding the patient's spinal cord stimulator's compatibility with magnetic resonance imaging (MRI), a MRI was not performed.

RESULTS

Given the symptomatic spinal cord compression and the presence of a calcified pannus, the decision was made to proceed with an EEA for odontoidectomy and pannus debulking to decompress the spinal cord. A C7-T1 laminectomies and occiput-T2 fusion were also completed to treat the subaxial cervical stenosis and stabilize the CVJ. Portable US was used intraoperatively to confirm adequate pannus resection and spinal cord decompression [Figure 3].

Surgical pathology confirmed inflammatory etiology of pseudotumor with histologic findings consistent with pseudogout. The patient did not develop any new postoperative sensory or motor deficits. At his latest follow-up (7 months) he exhibited marked improvement in upper and lower extremity strength, functional improvement in hand dexterity, as well as wheelchair independence. Follow-up CT and MRI confirmed adequate spinal cord decompression with intact occiput-T2 hardware [Figure 4].

DISCUSSION

Congenital pathologies at the CVJ include Chiari malformation, basilar invagination, and foramen magnum stenosis. Acquired pathologies include traumatic or pathologic fractures, osteomyelitis, and retro-odontoid pannus. The latter has a complex range of etiologies that can be grouped into rheumatoid and nonrheumatoid-associated etiologies.[11]

RA is the most common etiology for rheumatoid-associated pannus, in which the pannus formation is mediated by chronic inflammation of the synovial membrane, associated with bone and cartilage degradation at the medial atlantoaxial joint.[11]

Pannus progression compromises local stability and predisposes to subluxation of the atlantoaxial joints,

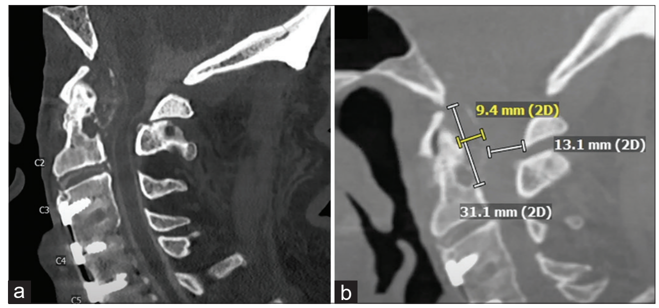

Figure 2: Preoperative computed tomography imaging demonstrating a retro-odontoid pannus narrowing the spinal canal causing spinal cord compression. There are peripheral eggshell calcifications in addition to significant erosion of the median atlantoaxial joint with retropulsion of the pannus into the anterior C1 arch and above the odontoid process (a and b). 2D: Two-dimensional

worsening the medullary brain stem and upper cervical cord compression during cervical spine flexion or extension.[4,5]

The optimal surgical approach for treatment of retro-odontoid panni has been a contested issue, especially given the complexity of the adjacent anatomy and importance of surrounding neurovascular structures.[11] Isolated anterior or posterior decompression, as well as posterior fusion alone, have been advocated as possible treatments by some authors.[12,13]

Anterior decompression followed by posterior fusion has been described as the accepted treatment protocol for this disease in the presence of myelopathy.[14] In the context of retro-odontoid pannus, anterior decompression optimizes the resolution of myelopathic symptoms, and posterior fixation is used to manage preexisting atlantoaxial instability (AAI)[12,13] or to manage induced AAI secondary to surgical decompression.

Posterior decompression without instrumented fusion has been described in symptomatic patients who do not present with preoperative atlantoaxial subluxation.[15] The posterior corridor for resection of retro-odontoid lesions has been successfully described in the treatment of ventral CVJ pathologies.[16] However, this technique confers a cumbersome trajectory to the lesion, limiting its accessibility and carries a higher risk of iatrogenic injury to nearby neurovascular

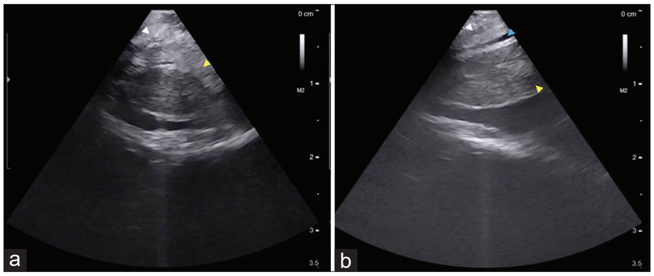

Figure 3: Intraoperative ultrasound image demonstrating predecompression retro-odontoid pannus (white arrowhead) with spinal cord compression (yellow arrowhead) in panel (a). Postdecompression image in panel (b) demonstrating dura matter with a thin layer of the transverse ligament (white arrowhead), decompressed spinal cord (yellow arrowhead), and visible anterior cerebral spinal fluid column (blue arrowhead)

structures. Moreover, lesion consistency is an important consideration for the approach, where dural adherence or calcified pannus could confer a greater risk of postoperative CSF leak and surrounding tissue damage during resection.[11]

Due to concern for spinal cord tethering, we determined that a posterior laminectomy alone would be insufficient for spinal cord decompression. A posterior laminectomy may exacerbate spinal cord compression when it is tethered over a ventral mass due to loss of posterior column stabilizing osseoligamentous structures.[1] Given the possibility of anterior spinal artery impingement and spinal cord ischemia, particularly in the presence of cervical myelopathy symptoms, we reasoned that direct pannus resection was a safer surgical approach.

Anterior spinal cord decompression and pannus resection are effective surgical techniques.[6-8,17,18] The surgeon must acknowledge that solely removing the anterior C1 arch and odontoid process is not sufficient to improve the patient's neurological status. Inadequate decompression may result in increased instability at the atlantoaxial junction and limited neurologic improvement. Therefore, it is crucial to debulk or completely resect the pannus.

Pannus resection is one of the most challenging steps, as aggressive debulking should be balanced with minimizing the risk of CSF leak. In the context of decompression and pannus resection, frameless stereotactic neuronavigation based on preoperative imaging is often utilized. However, this method is limited by the shift of the structures that occur during decompression and debulking of the pannus. In addition, neuronavigation on its own is ineffective at tracking and confirming complete spinal cord decompression.

The goal of the anterior approach is spinal cord decompression, not resection of the pannus in its entirety, and real-time image guidance can be a useful tool in achieving this goal. The

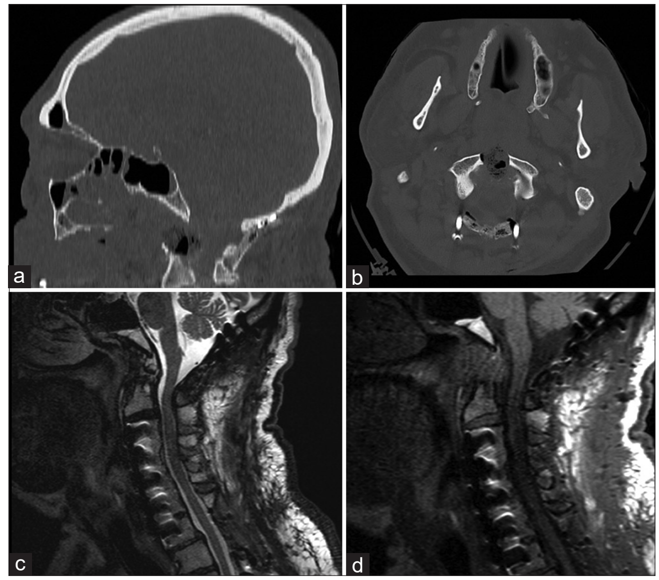

Figure 4: Immediate postoperative computed tomography (a and b) and postoperative T2 weighted (c) and T1 weighted (d) magnetic resonance imaging at 7 months postendoscopic endonasal approach and occipitocervical fusion demonstrating complete anterior spinal cord decompression and no pannus recurrence

intraoperative US is a valid option as it shows in real time the thickness of the pannus and whether further debulking is still required. Additionally, it confirms adequate spinal cord decompression by the visualization of a CSF column anterior and posterior to the spinal cord [Figure 3b and Video 1].

In the included video, the spinal cord exhibits a hyperechogenic border with an isoechogenic content pattern, as expected and previously described.[19,20] The CSF column was only identified posterior to the spinal cord before pannus resection, seen as a hypoechogenic space posterior to the spinal cord in the spinal canal. The anterior column was not initially identifiable as the pannus was obliterating this space. The intraoperative US demonstrates the pannus as a heterogenous hyperechogenic lesion [Figure 3a and Video 1]. After debulking, a CSF column anterior to the spinal cord is visualized, confirming adequate decompression [Figure 3b and Video 1].

Intraoperative US has been well described and proven helpful in various neurosurgical procedures. However, to our knowledge, this is the first report and operative video describing the utility of intraoperative US to guide retro-odontoid pannus resection through an EEA.

CONCLUSIONS

The authors demonstrate the use of intraoperative US to guide the resection of a rheumatoid retro-odontoid pannus. We highlight the use of this imaging modality when performing an endonasal odontoidectomy to confirm adequate spinal cord decompression in real time. We suggest that US should be included in the surgeon's armamentarium when performing these operations, as it provides additional information to supplement intraoperative decision-making and improves surgical accuracy.

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Conflicts of interest

Ricardo L. Carrau receives royalties from KLS Corp.

Daniel M. Prevedello is a consultant for Stryker Corp., Medtronic Corp., BK Medical, and Integra; he has received an honorarium from Mizuho and royalties from KLS-Martin and ACE Medical.

The other authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article.

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