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IDEAS AND TECHNICAL INNOVATIONS

A new technique: endoscopic transmass odontoidotomy

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Abstract

Background & objectives Basilar invagination (BI) represents a complex anomaly of the craniovertebral junction, characterized by the displacement of the odontoid process towards the foramen magnum. Current surgical interventions include anterior decompression and combined anterior-posterior decompression with posterior fusion. Traditional methods for odontoid resection encompass transoral, transnasal, and endonasal approaches. However, these techniques are fraught with significant risks. Furthermore, the restricted exposure provided by the endonasal corridor's anatomical limitations hampers surgical manipulation, prompting spine surgeons to seek alternative techniques. This report details a case of BI managed through an endoscopic posterolateral odontoidotomy, showcasing an innovative surgical approach. We aim to describe our experience in partially removing the odontoid via posterolateral approach with a novel endoscopic technique, preventing the need for additional approach and related complications.

Methods A 16-year-old male patient presented with complaints of imbalance and difficulty swallowing. Clinical examination revealed upper extremity muscle weakness, ataxic gait, and dysphagia. Upon the diagnosis of BI, a posterior occipitocervical fusion was performed. However, six months postoperatively, the patient returned with exacerbated symptoms. During the subsequent surgical intervention, the odontoid body was resected using a posterolateral transmass endoscopic approach. Due to the patient's neck and shoulder anatomy, cranial angulation of the endoscope was restricted, necessitating the retention of the odontoid tip.

Results Post-operative CT revealed that the tip was closer to the base and a subarachnoid space was formed. Follow-up CT after a year showed a complete migration of the tip to the base of C2 with a clear decompression of the brainstem.

Conclusion Our findings demonstrate that partial or total resection of the odontoid process via a posterolateral approach is feasible using endoscopic techniques. The endoscopic posterolateral transmass odontoidotomy should be considered a viable alternative method and route for patients necessitating partial or total odontoidectomy.

Keywords Basilar invagination · Endoscopic · Lateral mass · Odontoid · Resection

Introduction

Basilar invagination (BI), a condition associated with anomalies of the craniovertebral junction (CVJ) and cervical spine, presents a significant risk due to compression of the brainstem and spinal cord. This compression is caused by the protrusion of the odontoid process, leading to the narrowing of the spinal canal and foramen magnum. The primary treatment objectives for these patients are to decompress the brainstem and upper cervical spinal cord and to correct cervical alignment. The invaginated and posteriorly displaced odontoid process in BI is the primary factor contributing to neural injury. Furthermore, the surgical removal of the odontoid process can potentially exacerbate preexisting instability [1–2].

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The standard surgical approaches are anterior transoral/transnasal odontoidectomy and/or posterior suboccipital craniectomy and craniocervical fusion, followed by cervical laminectomy. The resection of the upwardly migrated odontoid is commonly performed through an anterior endoscopic endonasal approach [3].Complications such as vertebral artery injury, pharyngeal infection, cerebrospinal fluid (CSF) leakage, swallowing and respiratory complications have limited the widespread use of transoral and transnasal approach [4].

Consequently, the recently developed endoscopic endonasal approach has gained popularity [5]. However, despite the advantages of this technique, the limited exposure due to the anatomical constraints of the endonasal corridor has driven spinal surgeons to explore alternative methods. This led to the introduction of a novel posterior midline approach, known as the transaxis approach [6], which allows for safe and effective single-stage surgery. We postulated that a posterior endoscopic approach might be advantageous for performing endoscopic transmass odontoidotomy (ETO). This hypothesis was inspired by a previous cadaveric study, which demonstrated access to C1-2 lesions through the removal of the C1 posterior arch and the inferomedial aspect of the C1 lateral mass [7].

In this technical case report, we describe a patient with BI who had previously undergone posterior craniocervical fusion and presented with exacerbated symptoms six months postoperatively. Utilizing a posterolateral endoscopic transmass approach, we successfully removed the body of the odontoid. Follow-up observations revealed that the tip of the odontoid, under the pressure of CSF pulsations, had migrated inferiorly to the base of C2, thus alleviating the compression and allowing for free flow of CSF. This report may serve as a preliminary step towards establishing a new posterolateral endoscopic transmass odontoidotomy approach.

Case report

Under general anesthesia the patient was intubated in the supine position. The head was fixated using a Mayfield skull clamp and placed in the prone position on the surgical table and the shoulders were strapped (Fig. 1). The incision from the previous surgery was used for a midline approach extending from the inion to the C6 spinous process. The paravertebral muscles and scar tissue from the previous operation were dissected subperiosteally to remove the occipital plate, C2 pedicle and C3-4-5 lateral mass screws.

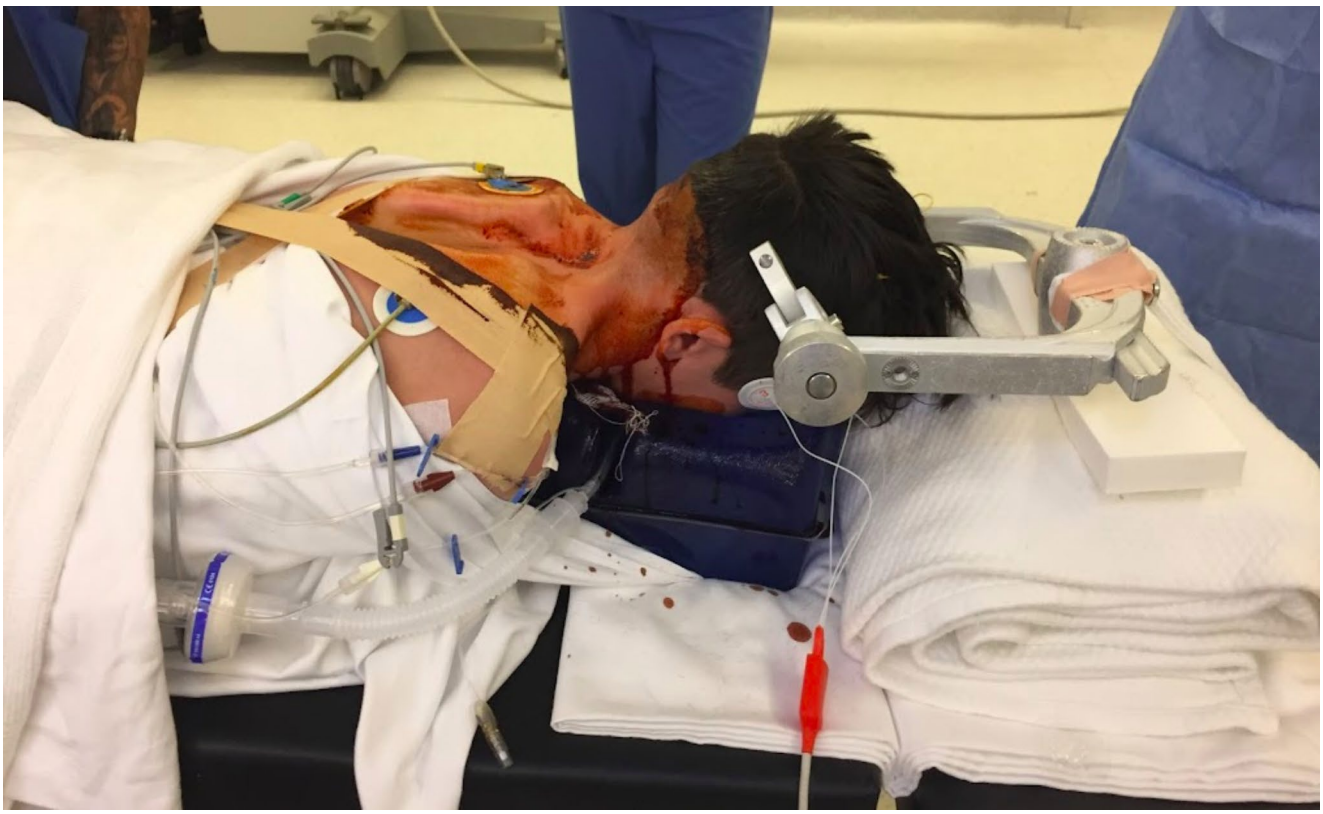

Fig. 1 Positioning of the patient. Note that even though the shoulders were strapped, Sprengel deformity (congenitally high scapula) commonly seen in Klippel-Feil patients is present

Under the surgical microscope, C1-2 facet joints were exposed and C2 roots were sacrificed after bipolar cauterization. A 2-mm diamond burr tip attached to a high speed drill was used to shave the superomedial side of the C1-2 facet joints bilaterally to allow for the working channel of the endoscope to reach the odontoid.

At the C2-3 intervertebral disc level distancing from the mid-line approximately 5 cm, bilateral skin incisions measuring 7 mm in length were made for the entry points of the endoscope (iLESSYS® interlaminar endoscopic surgical system, joimax®, Germany). First on the right side the endoscope was introduced through the incision aiming for the medial aspect of the C1-2 facet joint with a medial angle of 40° and cranial angle of 15–20° (Fig. 2). Due to the neck and shoulder anatomy (Fig. 1) and pre-existing scoliosis and Klippel Feil Syndrome of the patient, the cranial angle was limited at 20°. Following the trajectory of the C2 pedicle and the absent C2 roots, the endoscope was able to reach base of the odontoid without any significant dural contact. Then using a high speed drill with diamond burr tip, the lower half of the odontoid was removed (Fig. 3). The odontoid body was drilled until anterior longitudinal ligament. Endoscopic Kerrison ronger was also used to assist the odontoidotomy. The limitation of cranial angulation did not allow for a clear approach to the tip of the odontoid and thus was not removed. The same approach and procedures were repeated on the left side (Video).

The continuous irrigation allowed for effective hemostasis from the osseous structures. To prevent instability and achieve solid fusion, the lateral mass screws were revised

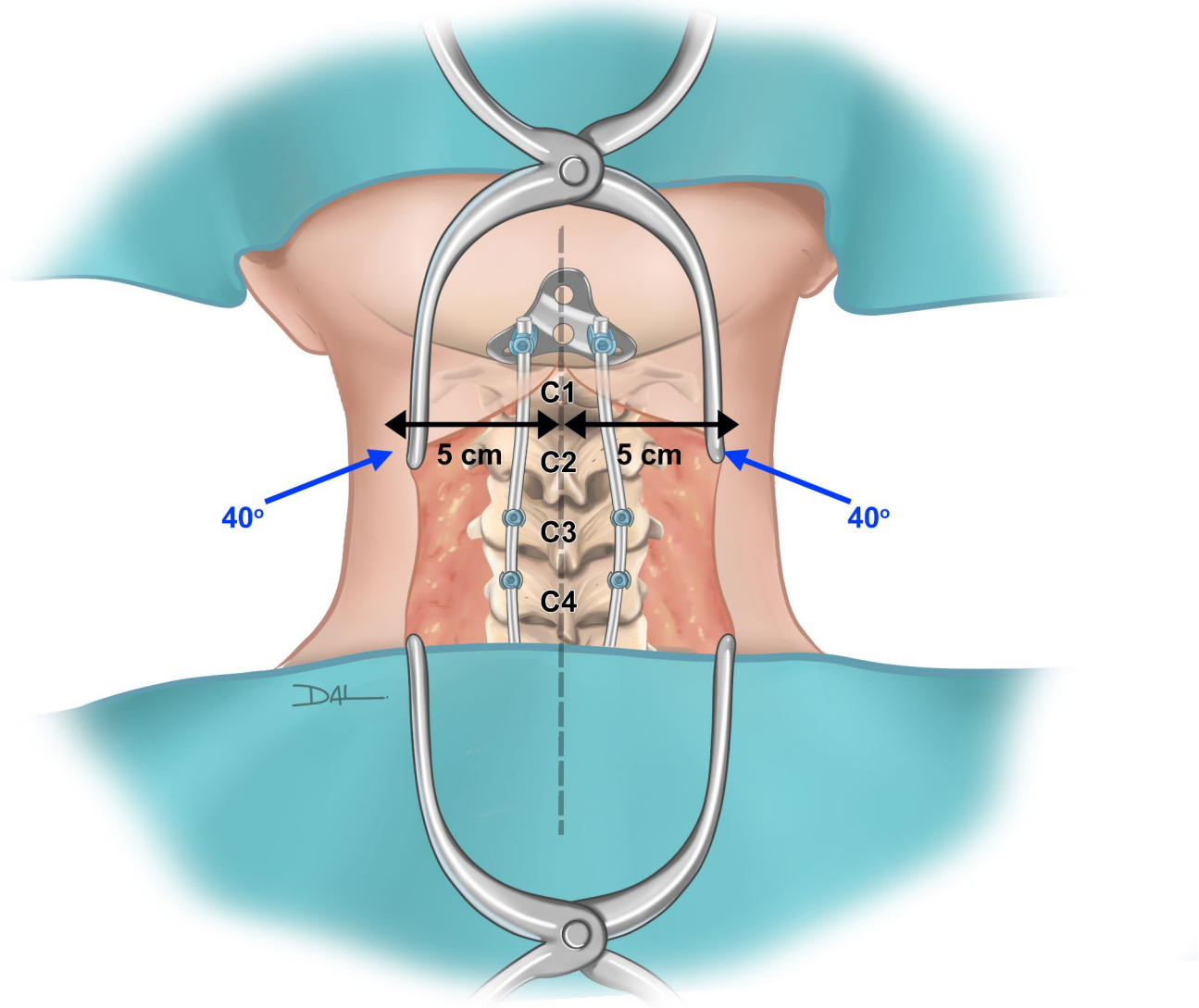

Fig. 2 Entrance point of the endoscope at the C2-3 intervertebral disc level with a medial angulation of 40°, distanced 5 cm laterally from the midline

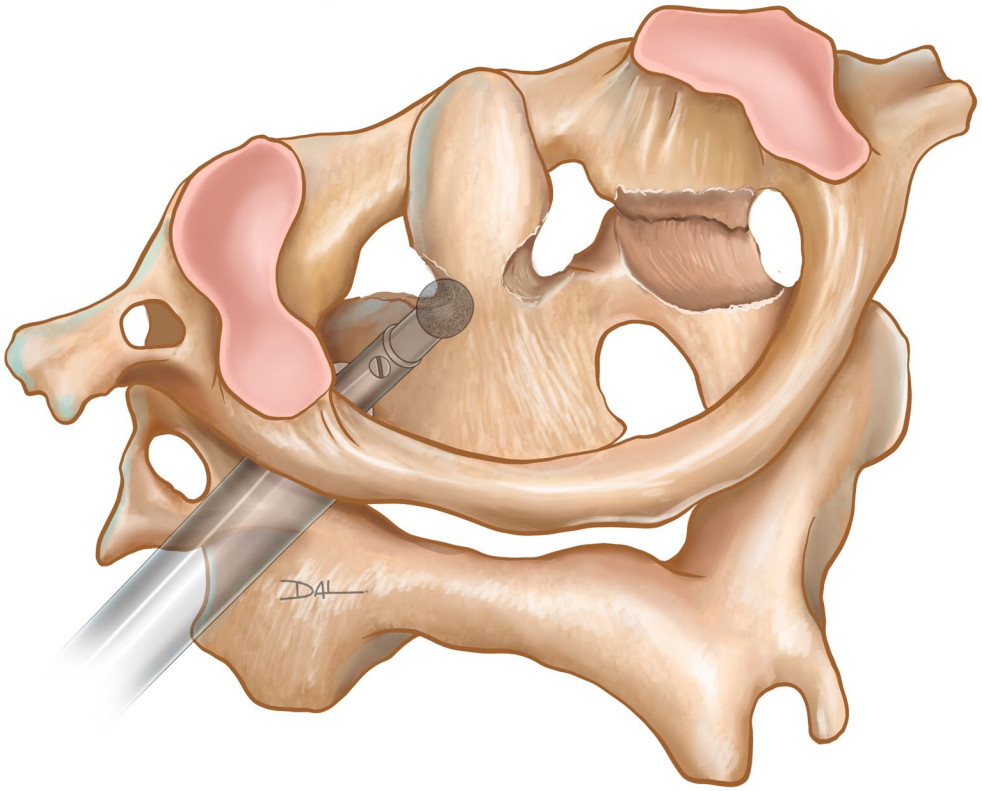

Fig. 3 Illustration of the endoscopic transmass approach. Note the removed medial aspect of the C1-2 facet joint

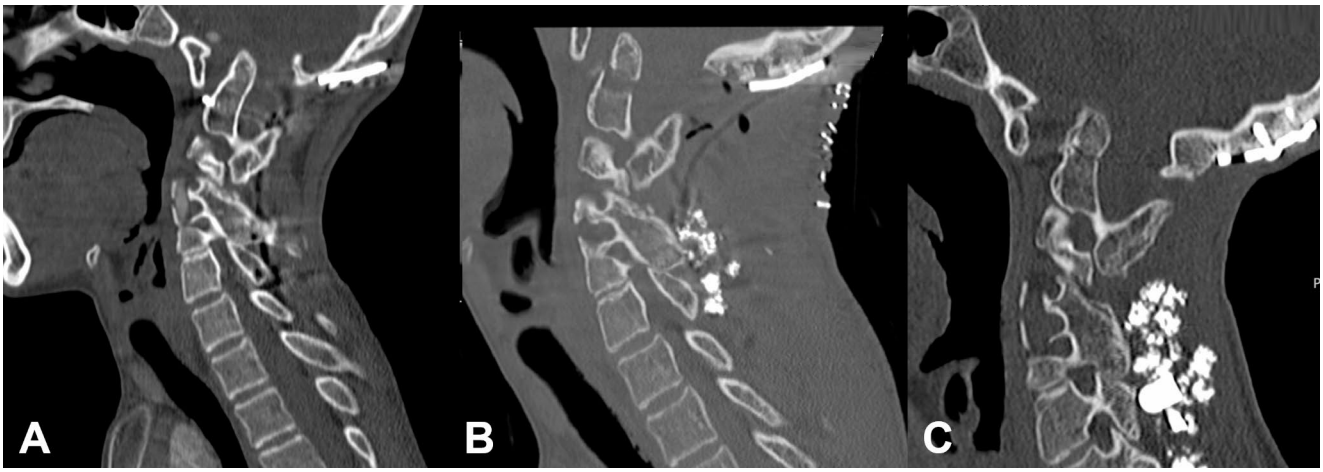

Fig. 4 Sagittal CT of the CVJ. **A**. Pre-endoscopic approach. **B**. Post-operative first day. **C**. 1 year follow-up. Note that the tip of the odontoid moved inferiorly with time alleviating the invagination

and autologous bone graft was placed. Subfascial drain was placed and all fascia, subcutaneous and skin layers were sutured. The patient was discharged uneventfully with nearly complete resolution of symptoms. No transfusion was necessary. The CT images before endoscopic approach, early post-operative period and first year follow-up are given in Fig. 4. The pre-operative invagination of the odontoid and post-operative flow of CSF can be seen on the MRI in Fig. 5.

Ethics and Consent

The patient's family was consented for the procedure and publication in a standard fashion. An institutional review board (IRB) was deferred given the nature of the report.

Fig. 5 **A**. Pre-operative MRI showing the basilar invagination. Note the lack of any CSF flow anterior and posterior to the brainstem. **B**. Post-operative MRI with a reduced odontoid and thin line of CSF flow around the brainstem

Discussion

C1-2 pathologies present unique surgical challenges compared to other vertebral segments due to their close anatomical relationships with the vertebral artery, foramen magnum, and spinal cord, as well as the potential for iatrogenic surgical instability. The odontoid process, in particular, may prove difficult for spinal surgeons to access. To address this issue, numerous surgical approaches have been developed. Transoral and transnasal approaches for odontoidectomy have been well documented, and the advent of endoscopic techniques has further refined and improved endonasal modalities [3]. However, these anterior approaches come with inherent disadvantages. The endoscopic endonasal approach, for instance, provides a very narrow exposure and limited working area, restricting the surgeon's maneuverability. Additionally, anterior odontoid approaches often necessitate a subsequent intervention for posterior fusion. To mitigate these limitations, and inspired by a cadaver study that demonstrated posterior access to C1-2 lesions [7], we employed a novel technique for odontoid removal: endoscopic transmass approach.

Although ETO allows for a single-stage approach to addressing CVJ pathologies, it presented a challenge in this case. The patient had long-standing kyphoscoliosis and Klippel-Feil syndrome, resulting in neck and shoulder anatomy that did not permit sufficient cranial angulation. Consequently, the tip of the odontoid process could not be removed. Intraoperatively, we hypothesized that CSF pulsations would eventually displace the tip toward the base. To facilitate this, we removed the inferior half of the odontoid, leaving no bone attachment and part of the transverse ligament to "loosen" the tip. Despite this, complete removal would have been preferable. We believe that in patients with normal cervical and shoulder anatomy, this endoscopic transmass approach would allow for effective cranial angulation and complete odontoid removal.

The endoscopic approach through the posteromedial aspect of the C1-2 facet joint provided a direct path to the odontoid without disrupting the dura mater. However, it is important to highlight that sacrificing the C2 nerve root is necessary with this approach. Moreover, this technique can also be adapted for accessing extradural lesions at the C1-2 level. Additionally, the transmass approach allowed us to avoid the rich venous plexus around the C2 nerve root. No vascular insult was caused since the working channel

through the bone avoided any traversing of the venous plexus. The venous plexus at this junction usually presents with significant hemorrhage, hindering a classic open or micro approach. A skin incision was made at the C2-3 level to facilitate adequate cranial angulation, although in this case, the patient's shoulder anatomy limited extensive angulation. We believe that in patients with nearly normal anatomy, greater angulation would enhance exposure for complete odontoid removal. Nonetheless, as demonstrated in this case, even though total odontoidectomy was not achieved, removing the body and base along with loosening the transverse ligament proved effective in a young patient. Older patients with extensive degenerative findings may not have the same flexibility to allow for the correction of the odontoid tip via CSF pulsation.

Limitations

This technical approach is derived from a single patient experience. Furthermore, the patient underwent initial macroscopic, followed by microscopic, and finally endoscopic procedures. Therefore, a purely endoscopic approach is essential to establish its effectiveness conclusively. The patient's anatomical variations also constrained complete odontoid removal allowing for odontoidotomy proved to be sufficient. However this underscores the need for studies involving more suitable patients undergoing a purely endoscopic approach.

Conclusion

ETO shows promise by obviating the necessity for anterior approaches while alleviating brainstem compression. It has demonstrated safety and effectiveness in a single patient, yielding satisfactory results during follow-up. However, larger case series are imperative to thoroughly assess the safety and efficacy of this technique.

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Author contributions IB: Conceptualization, methodology, software, writing original draft. SS, UUU: Investigation, data curation, surgery. AFO: Formal analysis, investigation, review and editing, supervision.

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Data availability All data related to this study can be requested from the corresponding author via e-mail.

Declarations

Ethics approval and consent to participate The study was carried out according to the latest revision of the Helsinki Declaration regarding medical research involving human subjects. Informed written consent was acquired from the patient and legal guardians before the study.

Consent for publication A written patient consent form from the patient and parents was obtained.

Informed consent Patient consent was obtained from the patient and legal guardians prior to the study to allow the publication of the results and all radiological images.

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Competing interests The authors have no competing interests related to this study.

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