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ORIGINAL ARTICLE

Lesson learned in endoscopic endonasal dens resection for C1–C2 spinal cord decompression

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Abstract

Purpose Endoscopic endonasal approach (EEA) is the safest and most effective technique for odontoidectomy. Nevertheless, this kind of approach is yet not largely widespread. The aim of this study is to share with the scientific community some tips and tricks with our ten-year-old learned experience in endoscopic endonasal odontoidectomy (EEO), which remains a challenging surgical approach.

Material and methods Our case series consists of twenty-one (10 males, 11 females; age range of 34–84 years) retrospectively analyzed patients with ventral spinal cord compression for non-reducible CVJ malformation, treated with EEA from July 2011 to March 2019.

Results The results have recently been reported in a previous paper. The only intraoperative complication observed was intraoperative cerebrospinal fluid (CSF) leak (9.5%), without any sign of post-operative CSF leak.

Conclusions Considering our experience, EEO represents a valid and safe technique to decompress neural cervical structures. Despite its technical complexity, mainly due to the use of endoscope and the challenging surgical area, with this study we encourage the use of EEO displaying our experience-based surgical tips and tricks.

Keywords Endoscopic endonasal approach · Odontoidectomy · Craniovertebral junction · Spinal cord decompression · C1–C2 instability

Introduction

The anterior approach to the atlantoaxial region was first described in 1935 by German in dogs and then in 1968 by Greenberg in humans [1]. From that point on, the transoral approach has been used extensively for different type of diseases, including basilar invagination, rheumatoid pannus in rheumatoid arthritis, odontoid fractures or nonunion, tumor and odontoid hypoplasia [2]. This approach was considered the gold standard for several decades; however, it requires retraction or splitting of the soft palate and can result in significant patient morbidity including dysphagia, velopharyngeal insufficiency and the possible need for tracheostomy Several studies began questioning the invasiveness and necessity of the transoral route compared to the less invasive and equally efficient endonasal or transcervical approach [3, 4].

Endoscopic endonasal approach (EEA) to the craniovertebral junction (CVJ) was first described in a cadaveric study by Alfieri et al. in 2002 and then, Kassam et al. in 2005 published the first case report of this procedure [2, 5]. This approach has been proposed to avoid the need to split the soft or hard palate, to retract the tongue, or to perform a glossotomy or mandibulotomy with the related

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sequelae and possible complications and to provide a more direct, panoramic, and shorter route to the odontoid [6].

In general, endoscopic endonasal odontoidectomy (EEO) requires a complete resection of the anterior arch of C1 to have an unobstructed access to the odontoid, followed by removal of the dens, the anterior atlanto-occipital membrane, and the alar and apical ligaments [2, 7, 8]. The stability of CVJ is intricate and depends on bony, ligamentous, and capsular structures [9]. For this reason, protection of crucial structures has a role in reducing post-operative instability. Various studies suggest that partial preservation of the anterior arch of C1 may reduce the destabilization of CVJ, favor less extensive fixation constructs, decrease the risk of future hardware failure and cranial settling [8, 10].

The aim of this study is to offer some tips and tricks with our ten years experience in EEO, which remains a challenging surgical approach [11, 12].

Material and methods

Our case series consists of twenty-one (10 males, 11 females; age range of 34–84 years) retrospectively analyzed patients with ventral spinal cord compression for non-reducible CVJ malformation, treated with EEA from July 2011 to March 2019 in our Neurosurgical Department. In every case pre-operative cervical magnetic resonance imaging (MRI), to detect spinal cord compression and radiological sign of myelopathy, and cervical spine dynamic X-ray, to evaluate reducibility, were performed (dynamic X-ray was not performed in case of acute presentation).

All patients underwent pre-operative computed tomography angiography (CTA) for intraoperative neuronavigation and to plan an eventual posterior fixation. In the immediate post-operative period, every patient underwent dynamic X-ray and computed tomography (CT) scan control in order to document CVJ decompression and to exclude instability. The clinical and radiological follow-up was scheduled at 1 and 6 months after surgery and then annually.

Results

Our series results have recently been reported in our previous works [11–14], they are summarized in Fig. 1. The only intraoperative complication observed was intraoperative cerebrospinal fluid (CSF) leak (9.5%), without any sign of post-operative CSF leak.

We also report main surgical steps and our tricks to better perform this surgery (Table 1).

Discussion

The team experience for this relatively rare surgical approach indication is now more than ten years old. Taking into account the low rate of complications and the good outcome of our patients, we consider the EEA the safest and most effective technique for odontoidectomy. Nevertheless, this kind of approach is yet not largely widespread. In consideration of this, the objective of this paper is to share with the scientific community our surgical tips and tricks to perform a successful and safe EEO rather than listing our results.

The traditional transoral-transpharyngeal approach is burdened with some disadvantages including deep surgical corridor and a relatively high risk of morbidity, such as post-operative dysphonia, contamination with oral flora, tongue edema, and prolonged intubation [15–22]. Alternative approaches for this route have been proposed through transcervical or endoscopic endonasal route [2, 23]. The transcervical approach through minimally invasive tubular retractors with endoscopically controlled dissection was described by Wolinsky et al. The major limit of this approach is the access to the lower third of the clivus because the angle of attack in relation to the chest makes unable to gain access [23]. The development in endoscopic surgery seems to offer the more favorable route for patient outcomes than the traditional transoral-transpharyngeal approach.

EEO approach was first described by Kassam et al. in 2005 [2]. The endonasal route takes advantage of a natural anatomical corridor to reach a deep-seated area, such as the CVJ, and allows a wide and direct approach to the dens even in cases with severe platybasia and high-positioned odontoid [6, 14]. The advantages, in comparison with the transoral approach, include the surgical trajectory, no need for palatal splitting, no tongue retraction and no oropharyngeal incision. Furthermore, it allows an entirely top-down resection of the clivus and odontoid, thus creating higher dominance during drilling and during the detachment of required ligaments [6]. In this regard, the endoscopic endonasal technique permits a quick removal of the orotracheal tube with a prompt resumption of oral feeding, as yet reported in our case series in 2022 [12].

The surgical technique of EEO needs various tricks and a meticulous surgical planning has a paramount role. Considering that an important limitation of the EEA to the CVJ is the caudal exposure, because of the anatomical limitations superiorly and inferiorly, in the pre-operative phase, it is crucial to predict the lower limit that can be reached. Traditionally, the most used predictor was the nasopalatine line, or Kassam line, that is constructed from the rhinion and the posterior nasal spine and terminates on

Fig. 1 Our series results from Penner et al. [12]

Patient no	Sex (M:F = 10:11)	Age at surgery (years) (mean 60.6)	Diagnosis	Clinical presentation	Symptoms duration	C1 anterior arch integrity	Posterior instrumentation
1	F	72	Basilar Impression, Chiari Syndrome	Headache, ataxia	> 12 mos	Yes	No
2	F	59	CVJ complex malformation	Headache, UE weakness (3/5)	> 12 mos	No	Yes, OCF + AAF
3	M	42	CVJ complex malformation	Neck pain, UE and LE weakness (4/5)	< 3 mos	Yes	No
4	F	65	RA, inflammatory pannus	Neck pain, headache, LE weakness (3/5)	> 12 mos	No	Yes, AAF
5	F	70	CVJ complex malformation	Neck pain, LE weakness (4/5), respiratory insufficiency	< 48 h	No	Yes, AAF
6	M	53	Basilar invagination, CVJ complex Malformation	Neck pain; headache; gait and sphincter disturbances	> 12 mos	Yes	No
7	F	51	Chiari Syndrome; Syringomyelia/ hydromyelia	Sensory loss; gait disturbances; cerebellar dysfunction	> 12 mos	Yes	No
8	M	66	CVJ complex malformation	Neck pain; headache; sensory loss; LE weakness (2/5) and UE weakness (3/5); sphincter disturbances; respiratory insufficiency	3–12 mos	No	Yes, AAF
9	F	71	Chondrosarcoma G2 (odontoid tip)	Limb Paresthesia; LE and UE weakness (4/5); gait and sphincter disturbances	> 12 mos	No	Yes, OCF + AAF
10	F	70	CVJ complex malformation	Neck and radicular pain; limb paresthesia; sensory loss; gait impairment	> 12 mos	Yes	No
11	M	62	CVJ complex malformation	Neck pain; LE and UE weakness (4/5); sensory loss;	3–12 mos	Yes	No
12	M	55	CVJ complex malformation	Neck pain; mild sensory loss; LE and UE weakness (4/5)	> 12 mo	Yes	No
13	F	68	CVJ complexmalformation	Limb paresthesia; sensory loss; unilateral LE and UE weakness (4/5); gait	3–12 mos	No	No
14	F	66	CVJ complex malformation	Radicular pain; Limb paresthesia; sensory loss; unilateral UE weakness (3/5); gait impairment	3–12 mos	No	Yes, AAF
15	M	84	CVJ complex malformation	Neck pain; Limb paresthesia; LE weakness (4-/5) and UE weakness (3/5); gait impairment	3–12 mos	No	Yes, AAF
16	M	73	Klippel–Feil Syndrome; CVJ complex malformation	Dysphagia; Dysphonia; LE and UE weakness (2/5); respiratory insufficiency; consciousness impairment;	< 48 h	No	Yes, AAF
17	M	16	Chordoma	None	3–12 mos	Yes	No
18	M	34	Chordoma	Neck pain	> 12 mos	Yes	No
19	F	68	CVJ complex malformation; basilar invagination	Limb paresthesia; sensory loss; gait disturbances; dysphagia; LE and UE weakness (4-/5)	> 12 mos	Yes	No
20	M	73	CVJ complex malformation	Neck pain	< 3 mos	Yes	No
21	F	78	RA, inflammatory pannus	UE weakness (2/5); LE weakness (1/5)	< 3 mos	No	Yes, AAF

Table 1 Our series results from Penner et al. [12]

Surgical phase	Tricks
1. Planning	Prediction of the lower limit of the approach with nasopalatine line or rhinopalatine line
	Neuronavigation using CTA sequences
	Evaluation of surgical instruments length
2. Positioning	More flexed patient head
	MEP and SSEP during positioning phase
3. Nasal phase	Two nostrils field
	Drilling of the posterior nasal spine
4. Dens exposure phase	U-shaped rhinopharyngeal flap
	Fiber laser for flap harvesting
	Mucosal debrider and/or S-shaped curved aspirator for flap detachment
5. Decompression phase	Ultrasonic bone curette for dens removal
6. End phase and closure	Intraoperative CT scan to verify the extent of bone removal
	Use of Foley catheter for U-shaped flap adhesion

cervical spine [24]. Recently, different studies considered as more accurate predictor the rhinopalatine line, that is constructed from the midpoint of a line between rhinion and the anterior nasal spine and terminates on C2, intersecting the posterior nasal spine [25–27]. A relevant trick in the planning phase is to consider surgical instruments length. It is important not to underestimate the depth of the surgical field because instruments may not be long enough to reach the odontoid region from the nose.

The neuronavigation is a fundamental tool both in the preoperative planning and during the surgical approach. In particular, the use of CTA sequences could be useful to analyze the carotid course, especially during the preparation of the U-shaped rhinopharyngeal flap. During the positioning phase, the head is always secured in a Mayfield fixation device. It is fundamental to put the head in a more flexed position compared to any other endoscopic endonasal procedure, in order to gain an improved exposure of the odontoid process and to promote the removal of its upper part. Considering that some patients arrive to the surgeon attention with not only spinal cord compression but also myelopathy, intraoperative neurophysiological monitoring is essential. In order to properly flex the patient head and before the preparation of the surgical field, motor evoked (MEP) and somatosensory evoked potentials (SSEP) must be run to avoid any spinal cord damage during positioning phase. In our opinion, MEP and SSEP are useful also during odontoid and pathological tissue resection to avoid any unwanted compression against the spinal cord.

The first step is to create two nostrils field to permit a four hands job. The surgeon then follows the inferior turbinate to reach the choanas and through them exposes the rhino-pharynx mucosa. As yet reported in our previous study, the drilling of the posterior nasal spine, situated between soft and hard palate, could be helpful to expand the route of access to the dens [12]. In the approaching phase, authors like Wu, Hankinson or Iacoangeli, proposed a midline linear incision or the direct skeletonizing of rhinopharyngeal mucosa [10, 28, 29]. In contrast, Magrini and then Mazzatenta et al. purposed a U-shaped rhinopharyngeal flap. The advantage of the flap is seen in case of accidental or planned intraoperative CSF leak to perform a waterproof plastic repair (Fig. 2). However, this is a complex and time-consuming maneuver and could cause blood loss; in our series we use a fiber laser (CH fiber laser [Dornier MedTech, Munich, Germany]) for the flap harvesting. This tool permits a clean cut, facilitating the detachment of the pharyngobasilar fascia. Never underestimate the strength necessary to detach the rhinopharyngeal flap; in this regard, other useful surgical tools to help during this maneuver are the mucosal debrider and an S-shaped curved aspirator. The real major risk is represented by a possible irregular midline carotid artery loop that could be dramatically injured during the flap preparation. This risk is limited by performing pre-operative CTA

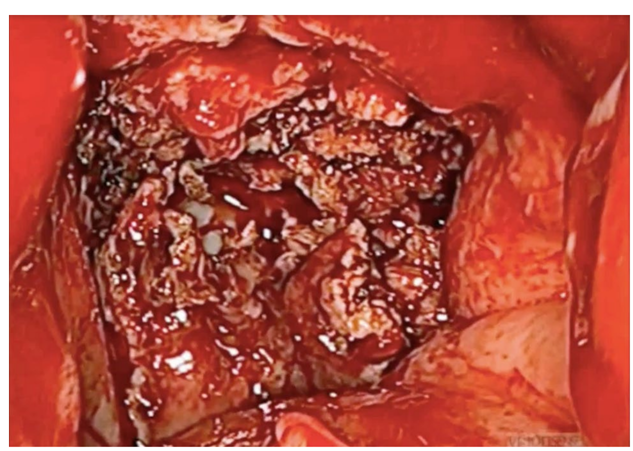

Fig. 2 The U-shaped rhinopharyngeal flap applied for reconstruction after the odontoidectomy

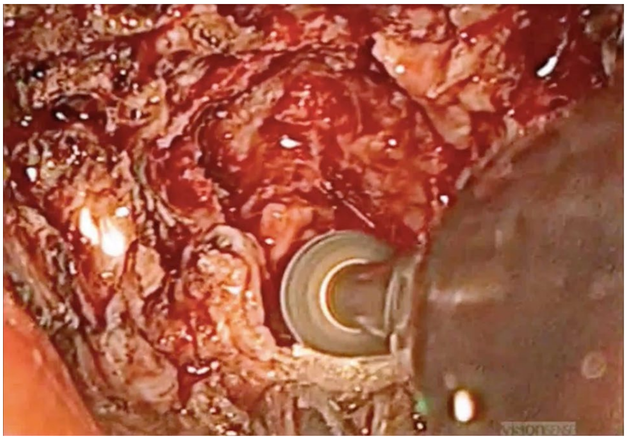

Fig. 3 High-speed drill for bone removal phase

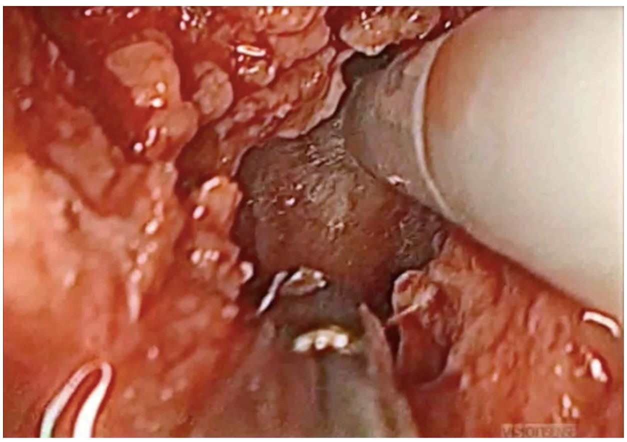

Fig. 4 Use of ultrasonic bone curette for bone removal phase

study and neuronavigation [6, 30]. At the end of surgery, the use of a posterior nasal mechanical compression with a Foley catheter is a helpful trick to improve the U-shaped flap adhesion in the post-operative phase [12].

After the exposure of C1–C2 anterior surface, in addition to usual high-speed drill, the use of an ultrasonic bone curette to remove the tip and the base of the odontoid is another relevant trick (Figs. 3 and 4). The ultrasonic bone curette is a comfortable tool in the endonasal approach to the CVJ because it provides a bone emulsification-irrigation-suction mechanism in single-hand and can reach deep field thanks to multiple size handle. It provides a selective bone emulsification based on longitudinal and torsional oscillation with a minimal thermal damage [13].

A debated argument regarding bone removal phase is occipitocervical stability. In contrast with the alternative approaches, like the transoral route, in which the entire C1 anterior ring and the base of the odontoid process are resected, or the transcervical route, in which the body and odontoid of C2 are resected, the EEA can give a great contribution to decrease the post-operative risk of spinal instability preserving the C1 anterior arch and resecting only the odontoid or the focal abnormality. Atlas ring integrity is an important element for craniocervical stability, in particular preventing the C1–C2 subluxation [15, 31]. Several authors performed a posterior C1–C2 fixation after an EEO with anterior C1 arch preservation, thus conserving more cervical mobility as compared to an occipitocervical fusion. As demonstrated (Iacoangeli et al.), the C1–C2 fixation has not to be systematically performed in old and frail patients with no evidence of pre-operative occipitocervical instability [10, 32, 33]. Furthermore, as reported by Iacoangeli, it could be considered safe to preserve the half-lower medial part of the arch to keep a solid continuity of the ring and to obtain a better access to the odontoid tip. When an adequate decompression is not obtainable without a total transection of the C1 anterior arch, a posterior fixation may be required [10, 14].

At the end of surgery, intraoperative CT scan could have a relevant role, showing the extent of bone removal and thus decompression effectiveness [12]. Asymmetrical bony removal, neuronavigation malfunctioning, missing of some part of the dethatched odontoid tip or subtotal tumor resection are problem that can be easily addressed with the use of intraoperative imaging.

Conclusion

Considering our experience, EEO represents a valid and safe technique to decompress neural cervical structures. Nevertheless, this approach is not widespread because its technical complexity, mainly due to the use of endoscope and the challenging surgical area. With this study, along with our previous one, we encourage the use of this technique displaying our experience-based surgical tips and tricks.

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Declarations

Conflict of interest None of the authors has any potential conflict of interest.

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