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Review Article

Nuances of Microsurgical and Endoscope Assisted Surgical Techniques to the Cranio-Vertebral Junction: Review of the Literature

Abstract

Purpose: An update of the technical nuances of microsurgical - endoscopic assisted approaches to the craniocervical junction (transnasal, transoral and transcervical) if provided from the literature in order to better contribute to identify the best strategy.

Methods: A non-systematic update of the review and reporting on the anatomical and clinical results of endoscopic assisted and microsurgical approaches to the craniocervical junction (CVJ) is performed.

Results: Pure endonasal and cervical endoscopic approaches still have some disadvantages, including the learning curve and the deeper surgical field. Endoscopically assisted transoral surgery with 30° endoscopes represents an emerging option to standard microsurgical techniques for transoral approaches to the anterior CVJ. This approach should be considered as complementary rather than an alternative to the traditional transoral-transpharyngeal approach.

Conclusions: Transoral (microsurgical or video-assisted) approach with sparing of the soft palate still remains the gold standard compared to the "pure" transnasal and transcervical approaches due to the wider working channel provided by the former technique. Transnasal endoscopic approach alone appears to be superior when the CVJ lesion exceeds the upper limit of the inferior third of the clivus. Of particular interest the evidence that advancement in reduction techniques can avoid ventral approach.

Introduction

Endoscopic endonasal, transoral and transcervical approaches have recently been developed as promising options to the traditional transoral microsurgery to the CVJ, and may become more mainstream as experience with these approaches increases (cons: learning curve, loss of 3-dimensional visualization) [1,2].

The transoral-transpharyngeal approach historically remains the "gold standard" for anterior approaches to the upper cervical spine when indicated according to the Menezes algorithm (Figure 1) [3]. However, there are still technical difficulties with the operating microscope, such as the need to see and work through a narrow opening in a deep cavity; to improve visualization; soft palate splitting and even hard palate resection along with extended maxillotomy are occasionally required. To overcome such complications, endoscopic assisted procedures for CVJ decompression have been developed. The endoscopic approaches to the CVJ include endoscopic endonasal approach, endoscopic transoral

approach, robot- assisted endoscopic transoral approach, combined endoscopic transnasal and transoral approach, and endoscopic transcervical approach [4,5]. The aim of the current review is to give an update on the anatomic fundamentals of endoscopic assisted surgery to the CVJ and to report on the available clinical results.

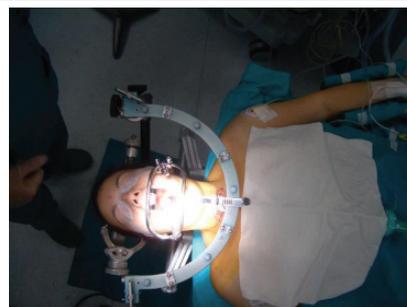


Figure 1: The Crockard distractor is applied into the oral cavity in order to allow the entrance of the endoscopic and surgical tools. Neuronavigation frame is put around the head for CT assisted CVJ decompression.

Anatomic studies on endoscopic craniocervical approaches

The most commonly used endoscopically assisted approaches to the craniocervical junction include transnasal, transoral and transcervical routes so far (Table 1) [2,6–22].

Endoscopic transoral approach: In 2004, de Divitiis et al., studied an endoscopic transoral–transclival intradural approach on 15 cadavers, without maxillotomy or mandibulotomy, and estimated a safe entry zone through the clivus endoscopically [7].

In 2006, Balasingam et al., conducted a cadaveric anatomical study to assess the area of surgical exposure and the available liberty of action for instrument manipulation by four surgical different approaches to the extracranial periclavicular region: traditional transoral route, transoral with a palate split, LeFort I osteotomy, and median labioglossomandibulotomy [8].

In 2009, Pillai et al., performed an odontoidectomy in 9 specimens by a direct transoral approach; endoscope assisted (5 cases) or combined endoscopic–microscopic aid, evaluating the surgical working area and the surgical freedom; the authors

Table 1: major findings in anatomical studies of endoscopic assisted approaches to the cranio cervical junction.

Author	Year	Approach	Major Findings
Ammirati and Bernardo [6]	1998	Endoscopic transoral approach	Median mandibulotomy/glossotomy or the LeFort I approach with hard palate splitting if atlanto-occipital and C1–C2 joints access is not necessary.
de Divitiis et al. [7]	2004		A limited clival and dural opening (20x15mm) allows full view of the anterolateral brainstem and cisternal spaces around it, from the spinomedullary junction to the interpeduncular cistern.
Balasingam et al. [8]	2006		Both median labioglossomandibulotomy as the classic transoral provide a good exposure of the CVJ but limiting exposure of the clivus, which was instead well visualized in its inferior third by the transoral route by a palate split. Maximal exposure of the extracranial clivus was gained by LeFort I approach.
Youssef [9]	2008		Mandibulotomy and mandibuloglossotomy decreased operative distance while increasing exposure in the axial and sagittal planes. Palatotomy increased rostral exposure without changing the caudal or axial exposure or the operative distance.
Pillai et al. [10]	2009		The use of an endoscope coupled with image guidance offers several advantages for providing access to the lower clivus and C1-C2 region
Dallan et al. [11]	2012		The combined transoral transnasal approach is the best answer to gain adequate space and optimal visualization in the rhinopharyngeal and upper clival region.
Alfieri et al. [12]	2002	Endoscopic transnasal approach	First description, in an anatomic study, of the endonasal route to the cranio-cervical junction, providing access from the anterior cranial fossa to the whole clivus, the upper cervical spine up to the body of C2.
Messina et al. [13]	2007		Data suggest as the binostril technique provides, without any additional surgical trauma, a better manoeuvrability of the surgical tools and the possibility to work with “three hands”.
Ciporen et al. [14]	2010		The combination of supraorbital or transorbital endoscopic pathways with transnasal approaches appear to improve anatomic target visualization in the central corridor of the anterior cranial fossa.
Aldana et al. [15]	2012		A line in the midsagittal plane, the NAXL, accurately predicted the lowest limit of the craniovertebral junction.
Little [16]	2013		Significant increase in angular range of motion during flexion-extension and axial rotation at C0-C1 joint after the inferior third clivectomy and intradural exposure of the foramen magnum, suggesting posterior surgical fusion.
Perez-Orribo [17]	2013		Increase of range of motion mostly in flexion/extension and less in axial rotation at the C0-C1 joint after removal of the lower third of the clivus and progressive occipital condylectomy.
Russo et al. [18]	2011	Endoscopic transcervical approach	The study described the microsurgical anatomy and the limits of exposure of the high anterior cervical, submandibular, approach to the clivus and foramen magnum, endoscopic assisted.
Baird et al. [19]	2009	Compared Approaches	Surgical goals of lower clival and odontoid decompression were achieved using the endonasal and transoral approach. The transcervical approach was unable to achieve more than 1 cm of lower clival resection, not allowing complete odontoid resection.
Seker et al. [20]	2010		Both transoral and transnasal approaches provide direct access to the CVJ avoiding neural and brain retraction but with a difference in level and extension of exposure. The transnasal endoscopic approach provides the shorter route to the CVJ while the transoral exposure gains a wider opening.
Visocchi et al. [2]	2014		The endoscope assisted transoral approach allows a better surgical control of the CVJ, in sagittal and transverse planes, providing a larger working channel and an easier manoeuvrability. The transnasal approach is limited in caudal direction down to the NPL; the transoral approach is limited in the rostral direction
Van Abel KM [21]	2015		According to a recent anatomical study, the lower incidence of post-operative dysphagia with the endonasal approach is likely related to the lower density of neuronal elements from the pharyngeal plexus above the palatal plane.
Visocchi et al. [22]	2015		SPIA (Surgical Palate Inferior Arcade) represents the maximal extent of the superior dissection for transoral approach. Interestingly it can be drawn by a simple lateral head X Ray examination by open mouth. SPIA is more reliable than NAXL

conclude that endoscope and image guidance allow to approach the ventral CVJ transorally with minimal tissue dissection, no palatal splitting, and no compromise of surgical freedom [10] (Figure 1).

Endoscopic endonasal approach: The main advantages of this endonasal approach to the ventral craniovertebral junction are minimal invasiveness, unlimited surgical access to the rostral midline craniocervical junction, avoidance of palatal split, and overall less operative morbidity compared with the transoral approach. Thanks to a relatively inclined surgical trajectory, in a rostral to caudal direction, the compressive pathology of basilar invagination, including the lower clivus and odontoid tip, may be removable without removing C1 anterior arch, thus maintaining stability of C1–C2 [23]. In 2009, Kassam's team published the concept of the "Nasopalatine line" (NPL) [23]. The NPL is a reliable predictor of the maximal length of inferior dissection, and odontoid surgery can safely be performed according to the preoperative radiological study of the potential anatomical limitations of the endonasal approach. In 2012 Aldana et al proved that a line in the midsagittal plane, the nasoaxial line (NAXL), connecting the midpoint of the distance from rhinion to the anterior nasal spine of maxillary bone and the C2 vertebra, tangential to the posterior nasal spine of palatine bone, accurately predicted the lowest limit of this approach on the cervical spine [15] (Figure 2).

Endoscopic transcervical approach: In 2011, Russo et al., [18] described the microsurgical anatomy and limits of exposure of the endoscopically assisted high anterior cervical, submandibular, approach to the clivus and foramen magnum; optimal route to access pathologies located ventral to the pontomedullary region. Two extensions of the approach were studied and described: an extended anterior far-lateral clivectomy and an inferior petrosectomy, thus extending the exposure to the anterior foramen magnum and the anterior cerebellopontine.

Comparison studies: In a study on 9 cadaver heads, in

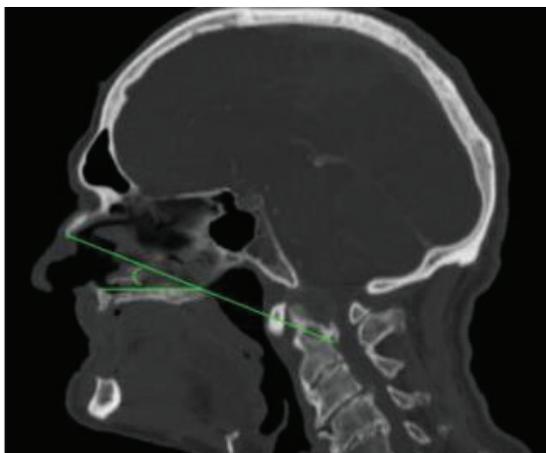


Figure 2: de Almeida JR, Zanation AM, Snyderman CH, Carrau RL, Prevedello DM, Gardner PA, Kassam AB. Defining the nasopalatine line: the lowest limit for endonasal surgery from the nasal bones down to the hard palate targeting the odontoid tip.

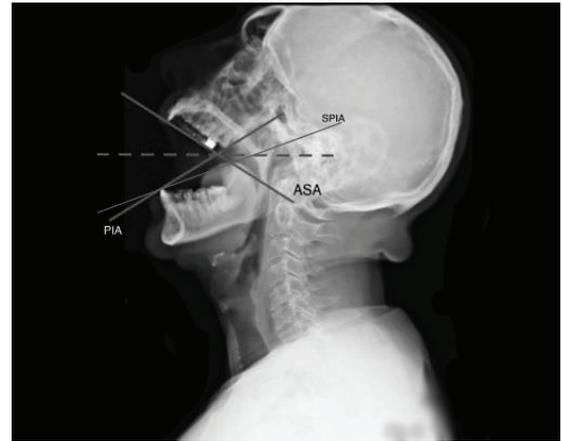


Figure 3: SPIA was found to be the line in the midsagittal plane that crosses in the midpoint two more lines: the RPIA and the Atlanto Superior dental Arch line (ASA) defined as the line joining the superior dental arch and the anterior base of Atlas. We defined the NPL and the PIA as the "hard tissue lines", since they both deal with bone tissue only and NAXL and (i.e. SNPL) and SPIA as "soft tissue lines", due to their relationship with soft tissues as the skin and the soft palate.

2009 Baird et al., assessed surgical access to the craniocervical junction using three endoscopic approaches: endonasal, transoral and transcervical. Data suggested that the surgical goals of lower clival and odontoid decompression were achieved using the endonasal and transoral approach, and the distance to the target area was shorter in the first one. The transcervical approach was unable to achieve more than 1 cm of lower clival resection, thus not allowing complete odontoid resection [19]. In 2010, Seker et al., Stated that transnasal endoscopic approach provided the shorter route to the CVJ while the transoral exposure gained a wider opening [20].

However, the two approaches should be considered complementary rather than alternative. When removing large lesions that extend from the upper clivus to below C2, the transnasal and transoral route may be successfully used combined. The transcervical approach has the clear clinical advantage of reducing the risk of meningitis, of cerebrospinal fluid leak, to maintain a sterile surgical field, familiar approach, and an optimal surgical trajectory for pathological findings lower than C2.

In 2012, Dallon et al. [11], investigated a new robotic surgical setting, DaVinci system, in two cadavers, comparing the traditional transoral, and the combined transoral transnasal procedures to the CVJ. They concluded that the lower the placement of the robotic arms, the easier the dissection of the rhinopharynx, basisphenoid and upper clivus.

Visocchi et al., compared the surgical exposition angle and the working channel volume of both transnasal and transoral approaches in the cadaver by means of a comparative neuroradiological "real time" study. They concluded that the transnasal approach, as widely discussed, is a viable strategy to reach the CVJ, but has limited angular (nostrils, choanae) and linear (NPL) surgical exposure, which in our view makes it suitable only for certain types of diseases and prevents its systematic applicability in other conditions, such as lateral tumors and pathologies caudal to C2. However, an obvious

advantage of this approach is that there is no need to cut the soft palate, which minimizes the potential postoperative morbidity, like swallowing disturbances and hyper-nasal speech, which have a major negative impact on the quality of life (lack palatine veil); the transoral approach provides a better exposure of the CVJ, both on the sagittal plane and on the transverse plane. Finally, the combination of the two approaches must be considered as an option to accomplish a particular surgical goal. From a purely anatomic point of view, the results of Visocchi et al., seem to suggest that in normal conditions, the transnasal approach to the CVJ is an oblique approach, which allows only the piecemeal removal of CVJ pathology and is not recommended for large tumors and low, and far laterally sited CVJ pathologies. The transnasal approach is limited in the caudal direction down to the NAXL; otherwise the transoral approach is limited in the rostral direction with a maximum to the foramen magnum in a normal specimen [24]. In a further study Visocchi has confirmed the NAXL to be a reliable preoperative predictor of the maximal extent of inferior dissection for transnasal approach. Moreover the Author has identified the corresponding palatal line for evaluating the upper limit of the transoral approach (from the

inferior dental arch up to the hard palate) which represents the maximal extent of superior dissection and called it the Surgical Palate Inferior Arcade (SPIA); interestingly it can be drawn by a simple lateral head X Ray examination by open mouth. The NAXL appears to vary more than the SPIA. Finally Pros and cons of the each approach have to be taken into account as well as the choice of a combined transoral and transnasal approach. [22] (Figure 3).

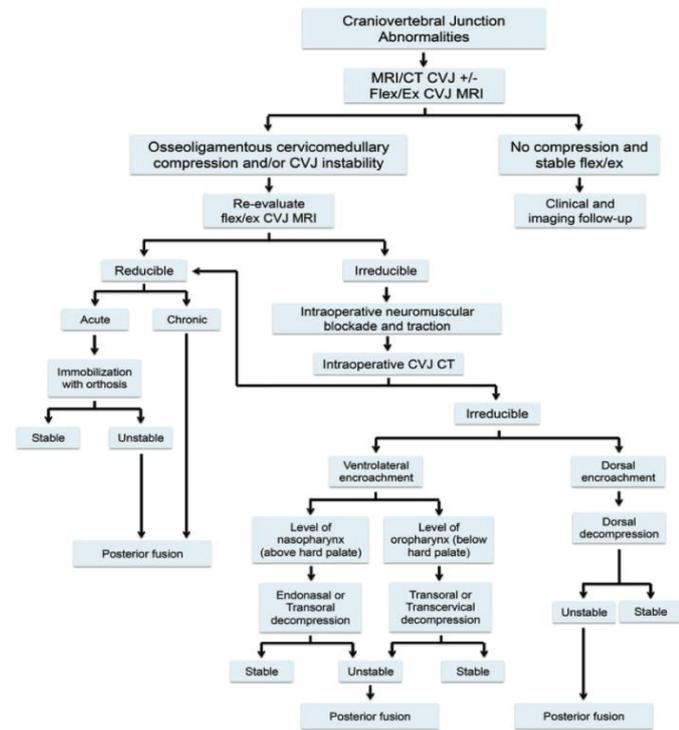
Surgical studies (Table 2) [3,25-45]: About associated complications, Valero et al., 2015 [42] in a comprehensive literature search of several databases indexing English-language literature published from 1990 to November 13, 2014, reported CSF leak in 18%. However, it was present in only 3 patients (4.2%) postoperatively. One patient developed meningitis that was complicated by sepsis and death, resulting in a procedure-related mortality of 1.4%. Transient velopharyngeal insufficiency was seen in 3 cases (4.2%) and 2 patients had respiratory failure in the perioperative period.

Liu et al., 2015 [46] published the technical nuances used in their institution. In particular they use 2 surgeons (neurosurgeon and otolaryngologist) 3 to 4 hand approach

Table 2: Surgical results of endoscopic assisted surgery to the craniocervical junction

Author	Approach	N° P.	Patient Disease	Mean Age	Associated posterior fusion	Complication
Frempong- Boadu et al. [25]	Endoscopic transoral approach	7	3 congenital anomalies, 1 degenerative, 1 traumatic, 1 pseudogout granulation mass, 1 neoplasm	49,3	6\7	1 death for a myocardial infarction
Kassam et al. [26]	Endoscopic transoral approach	1	1 degenerative	73	1\1	None
Husain et al. [27]	Endoscopic transoral approach	11	7 congenital anomalies, 2 trauma, 2 degenerative	27,7	11\11	2 pharyngeal wound dehiscence, 1 immediate post op neurologically worsening, 2 posterior wall infection
Wolinsky et al. [28]	Endoscopic transcervical approach	3	3 congenital anomalies	61,6	3\3	1 intraoperative CSF leak
Wu et al. [29] McGirt et al.	Endoscopic endonasal approach	3	2 degenerative, 1 traumatic	44	3\3	1 CSF leakage intraoperative
McGirt et al. [30]	Endoscopi transcervical approach	4	4 Congenital anomalies	14	4\4	1 subluxation in Halo vest
[31] Menezes et al.	Transoral approach	280	267 Congenital anomalies, tumors (7), other (6)	16	280\280	2 pharyngeal wound dehiscence, 5 velopalatine incompetence
Perrini [32]	Transoral approach	34	34 Congenital anomalies	55	32\34	2 dural lacerations, 1 oral wound dehiscence, 2 urinary infection, 2 pulmonary embolism, 1 pseudoarthrosis, 1 velopharyngeal dysfunction, 4 deep vein thrombosis, 2 posterior wound infection, 1 chest infection
El-Sayed et al. [33]	Transoral approach (3) Combined endoscopic transnasal and transoral approaches (8)	11	ENDO: 2 tumors, 2 infections, 1 degenerative, 3 congenital anomalies, open : 3 degenerative	54	No report	Dysphagia, airways complications
Lee et al. [34]	Endoscopic transnasal approach	4	1 degenerative, 2 congenital anomalies, 2 neoplasm	48	4\4	1 intraoperative CSF leak
Visocchi et al. [35]	Endoscopic transoral approach	7	3 neoplasm, 1 traumatic, 1 degenerative, 2 congenital anomalies	01/06/78	6\7	None
Salunke et al. [36]	Transoral approach	24	24 congenital anomalies	01/05/60	15\24	4 prolonged ventilation, 1 CSF leak, 1 residual compression, 4 pharyngeal wound infection

Dhaliwal et al. [37]	Transoral approach	22	7 neoplasm, 7 congenital anomalies, 6 degenerative	50	19\22	1 spinal cord injury, 1 durotomy, 2 wound complication, 1 hardware failure, 3 prolonged dysphagia, 6 infections, 5 respiratory distress, 2 deep vein thrombosis.
Gladi et al. [38]	Endoscopic endonasal approach	4	4 degenerative	74	2\4	None
Dasenbrock et al [39]	Endoscopic transcervical approach	15	5 degenerative, 9 congenital anomalies	42	15\15	2 urinary tract infection, 2 upper airway swelling, 2 dysphagia, 1 asymptomatic pseudomeningocele
Choi and Crockard [40]	Transoral approach	533	95 congenital anomalies, 216 degenerative, 34 traumatic, 100 tumors, 14 infections, 20 other conditions	46,3	228\533	6 CSF leak, 11 sepsis, 13 Meningitis, 34 infections, 19 cardiovascular complications, 71 respiratory complications, 15 dysphagia, 2 hematoma, 33 velopharyngeal incompetence, 4 cranial nerve palsy, 20 fixation failure, 7 Subaxial instability requiring surgery, 5 paralysis, 9 other complications
Hickman et al. [41]	Endoscopic transnasal approach	2	2 congenital anomalies	11/12/15	2\2	1 incomplete resection of the odontoid process, 1 minimal swallowing impairment
Morales-Valero [42]	Endoscopic transnasal approach	Review	The endoscopic endonasal approach, rather than an alternative, should be considered a complementary approach to the standard transoral-transpharyngeal route	55,8		CSF leak intraoperative 18% and 4,2% post-operative; Mortality 1,4%, transient velopharyngeal insufficiency; 2 patients respiratory failure
Gladi [38]	endoscopic transnasal	4	rheumatoid pannus and basilar invagination		2\4	none
Chaudry [43]	endoscopic transnasal	1	BI and moderate cranial settling	47	no	intermittent mild dysphagia
Ponce-Gomez [44]	5 endoscopic transnasal 7 transoral microsurgical	12	craniovertebral junction instability	18-52	12\12	From the transoral group, 2 patients had postoperative dysphonia, 1 patient presented with dysphagia, and 1 patient had intraoperative CSF leakage. The endoscopic procedure required longer surgical time, less time to extubation and oral feeding, a shorter hospital stay, and no complications in this series
Menezes [3]	Transoral approach	800	In small children an endonasal approach may be limited by the small nares. If reduction cannot be achieved, a 540° procedure may be necessary in some cases (depending on the pathology), whereby the posterior approach and incision is temporarily closed and the patient is repositioned supine for a ventral decompression followed by reopening of the posterior incision and the patient is repositioned supine for a ventral decompression followed by reopening of the posterior incision and posterior fixation. All patients undergo neck flexion\ extension MRI of the CVJ. The patient is positioned supine with crown halo with traction; an intraoperative 3D CT is obtained in traction. The patient is then placed prone and another 3D CT is obtained. The algorithm is updated Figure 1			Velopharyngeal insufficiency 1,8% pharyngeal wound dehiscence 0,7%
Terry C. Burns [45]	endoscopic transnasal	2	Ventral epidural abscess with osteomyelitis at the craniocervical junction	69, 55	2\2	CSF leak



via a binostrils access. They start with a 30° angles HD 4 mm endoscope. A 0° endoscope is preferred in cases of cranial settling in which the odontoid is located very high, above the hard palate. A pedicled naso-settal flap is prepared on both sides. In some cases of platybasia, it may be necessary to perform a sphenoidotomy and extend the midline incision from the floor of the sphenoid sinus down to the inferior clivus, especially if the odontoid process is located in a retroclival position.

Menezes at al., [3] underlines the importance of the intraoperative reduction strategies. If reduction cannot be achieved, a 360° procedure may be necessary in some cases (depending on the pathology), the patient is positioned supine for a ventral decompression followed by posterior incision and posterior fixation. Moreover all patients undergo neck flexion\ extension MRI of the CVJ. The patient is positioned supine with crown halo with traction; an intraoperative 3D CT is obtained in traction. The patient is then placed prone and another 3D CT is obtained. The algorithm is updated.

Conclusions

The progressive worldwide blooming of transoral procedures, thanks to the intensive care and the improvements in intraoperative neurophysiological monitoring techniques (once considered pioneering and very selective), is spreading the expertise in this field of surgery to a new population of surgeons. These techniques are performed alone or in conjunction with posterior procedures [47].

Pure endonasal and cervical endoscopic approach deserves consideration but still has some disadvantages: (1) the

learning curve and (2) the lack of 3-dimensional perception of the surgical field which could be an operationally limiting factor. Image clarity will be diminished when endoscopes smaller than 2.7 mm are used. Standard 4-mm endoscopes give a good image quality, but 2.7-mm scopes provide better maneuverability; (3) a limited working channel, according to the variability of the NAXL, which can make it difficult to remove huge tumors.

In our opinion, endoscopically assisted transoral surgery with 30° endoscopes represents an emerging alternative to standard microsurgical techniques for transoral approaches to the anterior CVJ. Used in conjunction with traditional microsurgery and intraoperative fluoroscopy, it provides a safe and improved method for anterior decompression with or without a reduced need for extensive soft palate splitting, hard palate resection, or extended maxillotomy. Virtually no surgical limitations do exist for endoscopically assisted transoral approach, compared with the pure endonasal and transcervical approaches to the CVJ in normal anatomical conditions.

So far, the endoscope deserves an interesting role as “support” to the standard transoral microsurgical approach since 30° angulated endoscopy strongly improves the visual but not the working channel and volume, even though the soft palate splitting is often still required. In our opinion transoral (microsurgical or video-assisted) approach with sparing of the soft palate still remains the gold standard compared to the “pure” transnasal and transcervical approaches due to the wider working channel provided by the former technique. Transnasal endoscopic approach alone appears to be superior when the CVJ lesion exceeds the upper limit of the inferior third of the clivus. Furthermore, combined transnasal and transoral procedures can be tailored according to the specific pathological and radiological findings. Finally, experience is required with greater numbers of patients and long-term follow-up to further validate all the endoscopic techniques. In our opinion and in agreement with other authors, the endoscopic endonasal approach, rather than an alternative, should be considered a complementary approach to the standard transoral- transpharyngeal route [42].

According to a recent anatomical study, the lower incidence of post-operative dysphagia with the endonasal approach is likely related to the lower density of neuronal elements from the pharyngeal plexus above the palatal plane [21].

However, the time to extubation and oral feeding was significantly shorter in the endonasal group. Similarly Ponce-Gómez and colleagues reported their own series of patients treated using both approaches and found comparable rates of neurological improvement after odontoidectomy, with less time to extubation and oral feeding, as well as shorter hospital stay in the endonasal group [35].

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