Direct and Oblique Approaches to the Craniovertebral Junction: Nuances of Microsurgical and Endoscope-Assisted Techniques Along with a Review of the Literature

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Abstract

Purpose

The aim of this review is to provide an update of the technical nuances of microsurgical and endoscopic-assisted approaches to the craniovertebral junction (transnasal, transoral, and transcervical), and to report on the available clinical results in order to identify the best strategy.

Methods

A nonsystematic update of the reviews and reporting on the anatomical and clinical results of endoscopic-assisted and microsurgical approaches to the craniovertebral junction (CVJ) was performed.

Results

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

Conclusions

The transoral (microsurgical or video-assisted) approach with sparing of the soft palate still remains the gold standard compared with the "pure" transnasal and transcervical approaches, due to the wider working channel provided by the former technique. The 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 is the evidence that advances in reduction techniques can avoid the ventral approach.

Keywords Craniovertebral junction • Transoral approach • Transnasal approach • Transcervical approach

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Introduction

Endoscopic endonasal, transoral, and transcervical approaches have recently been developed as promising alternatives to traditional transoral microsurgery for the craniovertebral junction (CVJ), and these approaches may become more mainstream as experience with them increases (drawbacks of these newer approaches are a steeper learning curve and loss of three-dimensional visualization) [40, 41].

The transoral-transpharyngeal approach historically remains the "gold standard" for anterior approaches to the upper cervical spine when indicated according to the Menezes algorithm [15]. However, there are still technical difficulties with the operating microscope, such as the need to see and

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work through a narrow opening in a deep cavity and the need 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 have been developed for CVJ decompression. The endoscopic approaches to the CVJ include the endoscopic endonasal approach, the endoscopic transoral approach, the robot-assisted endoscopic transoral approach, combined endoscopic transnasal and transoral approaches, and the endoscopic transcervical approach [18, 22]. The aim of the present review is to provide an update on the anatomical fundamentals of endoscopic-assisted surgery for the CVJ and to report on the available clinical results.

Anatomical Studies of Endoscopic Craniovertebral Approaches

At present, the most commonly used endoscopically assisted approaches to the CVJ include the transnasal, transoral, and transcervical routes (Table 1).

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 achieved endoscopically through the clivus [10].

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 different surgical approaches to the extracranial periclival region: the traditional transoral route, transoral with a palate split, LeFort I osteotomy, and median labioglossomandibulotomy [4].

In 2009, Pillai et al. performed an odontoidectomy in nine specimens by a direct transoral approach; endoscope-assisted (five cases) or a combined endoscopic-microscopic procedure, evaluating the surgical working area and the surgical freedom; the authors concluded that the endoscope and image guidance allowed them to approach the ventral CVJ transorally with minimal tissue dissection, no palatal splitting, and no compromise of surgical freedom [31].

Endoscopic Endonasal Approach

The main advantages of the endoscopic endonasal approach to the ventral CVJ are minimal invasiveness, unlimited surgical access to the rostral midline CVJ, avoidance of palatal split, and less operative morbidity overall 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 the C1 anterior arch, thus maintaining the stability of C1–C2 [2]. In 2009, Kassam's team published the concept of the "nasopalatine line" (NPL) [12]. The NPL is a reliable predictor of the maximal length of inferior dissection, and odontoid surgery can be performed safely according to a 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 the rhinion to the anterior nasal spine of the maxillary bone and the C2 vertebra, tangential to the posterior nasal spine of the palatine bone, accurately predicted the lowest limit of this approach on the cervical spine [1].

Endoscopic Transcervical Approach

In 2011, Russo et al. [35] described the microsurgical anatomy and limits of exposure of the endoscopically assisted high anterior cervical, submandibular approach to the clivus and foramen magnum; the 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 region.

Comparison Studies

In a study on nine cadaver heads, in 2009, Baird et al. assessed surgical access to the craniovertebral 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 approaches, and the distance to the target area was shorter in the first approach. The transcervical approach was unable to achieve more than 1 cm of lower clival resection, thus not allowing complete odontoid resection [5]. In 2010, Seker et al. reported that the transnasal endoscopic approach provided a shorter route to the CVJ, while the transoral approach achieved a wider opening [36].

Table 1 Major findings in anatomical studies of endoscopic-assisted approaches to the craniovertebral junction (CVJ)

Author	Year	Approach	Major findings
Ammirati and Bernardo [3]	1998	Endoscopic transoral approach	Median mandibulotomy/glossotomy or the LeFort I approach with hard palate splitting if atlanto-occipital and C1–C2 joint access is not necessary
de Divitiis et al. [10]	2004		A limited clival and dural opening (20 × 15mm) allows full view of the anterolateral brainstem and cisternal spaces around it, from the spinomedullary junction to the interpeduncular cistern
Balasingam et al. [4]	2006		Both median labioglossomandibulotomy and the classic transoral route provide good exposure of the CVJ but limited exposure of the clivus, which was, instead, well visualized in its inferior third by the transoral route with a palate split. Maximal exposure of the extracranial clivus was gained by the LeFort I approach
Youssef [46]	2008		Mandibulotomy and mandibuloglossotomy decreased operative distance, while increasing exposure in the axial and sagittal planes. Palatectomy increased rostral exposure without changing the caudal or axial exposure or the operative distance
Pillai et al. [31]	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. [2]	2002	Endoscopic transnasal approach	First description, in an anatomical study, of the endonasal route to the craniovertebral junction, providing access from the anterior cranial fossa to the whole clivus and the upper cervical spine up to the body of C2
Messina et al. [27]	2007		Data suggest that the binostril technique provides, without any additional surgical trauma, better maneuverability of the surgical tools and the possibility to work with “three hands”
Ciporen et al. [7]	2010		The combination of supraorbital or transorbital endoscopic pathways with transnasal approaches appears to improve anatomical target visualization in the central corridor of the anterior cranial fossa
Aldana et al. [1]	2012		A line in the midsagittal plane, the nasoaxial line (NAxL), accurately predicted the lowest limit of the CVJ
Little [24]	2013		Significant increase in angular range of motion during flexion/extension and axial rotation at the C0-C1 joint after inferior-third clivectomy and intradural exposure of the foramen magnum, suggesting posterior surgical fusion
Perez-Orribo [32]	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. [35]	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, endoscopically assisted

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Table 1 (continued)

Author	Year	Approach	Major findings
Baird et al. [5]	2009	Compared approaches	Surgical goals of lower clival and odontoid decompression were achieved using the endonasal and transoral approaches. The transcervical approach was unable to achieve more than 1 cm of lower clival resection, not allowing complete odontoid resection
Seker et al. [36]	2010		Both transoral and transnasal approaches provide direct access to the CVJ, avoiding neural and brain retraction, but with a difference in level and extent of exposure. The transnasal endoscopic approach provides the shorter route to the CVJ, while the transoral exposure gains a wider opening
Visocchi et al. [41]	2014		The endoscope-assisted transoral approach allows better surgical control of the CVJ, in sagittal and transverse planes, providing a larger working channel and easier maneueverability. The transnasal approach is limited in the caudal direction down to the nasopalatine line (NPL); the transoral approach is limited in the rostral direction
Van Abel [38]	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. [47]	2015		The surgical palate inferior arcade (SPIA) represents the maximal extent of the superior dissection for the transoral approach. Interestingly, it can be drawn by a simple lateral head X-ray examination with open mouth. SPIA is more reliable than NAxL

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

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

Visocchi et al. [42] compared the surgical exposition angle and the working channel volume of both the transnasal and transoral approaches in a cadaver, by means of a comparative neuroradiological "real-time" study. They concluded that the transnasal approach, as widely discussed, is a viable strategy for reaching the CVJ, but that this approach 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; this minimizes potential postoperative morbidities, such as swallowing disturbances and hypernasal speech, which have a major negative impact on the quality of life (if there is a palatine veil dysfunction). 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 for accomplishing a particular surgical goal. From a purely anatomical point of view, the results of Visocchi et al. seem to suggest that, in normal anatomical 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, whereas the transoral approach is limited in the rostral direction in an anatomically normal specimen [42]. In a further study, Visocchi and colleagues have confirmed the NAxL to be a reliable preoperative predictor of the maximal extent of inferior dissection for the transnasal approach. Moreover, these authors 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; they called it the surgical palate inferior arcade (SPIA), and,

interestingly, it can be found by a simple lateral head X-ray examination with open mouth. The NAxL appears to vary more than the SPIA. Finally, the pros and cons of each approach have to be taken into account, as well as the choice of a combined transoral and transnasal approach [47].

Surgical Studies (Table 2)

In regard to complications associated with the endoscopic endonasal approach, Valero et al., in 2015 [29], in a comprehensive literature search of several databases indexing the English-language literature published from 1990 to November 13, 2014, reported cerebrospinal fluid (CSF) leakage in 18 % with this approach. One patient developed meningitis that was complicated by sepsis and death, resulting in a procedure-related mortality of 1.4 %. Transient velopharingeal insufficiency was seen in three patients (4.2 %) and two patients had respiratory failure in the perioperative period.

Liu et al. 2015 [26] reported the operative technique and technical nuances used in their institution. In particular they use two surgeons (neurosurgeon and otolaryngologist) with a three- to four-hand approach via binostril access. They start with a 30° angled HD (Hight Definition) 4-mm endoscope. A zero degree endoscope is preferred in cases of cranial settling in which the odontoid is located very high, above the hard palate. A pedicled nasoseptal

Table 2 Surgical results of endoscopic-assisted surgery for the craniovertebral junction

Author	Approach	No. of patients°	Patient disease	Mean age (years)	Associated posterior fusion	Complications
Frempong-Boadu et al. [17]	Endoscopic transoral approach	7	3 congenital anomalies, 1 degenerative, 1 traumatic, 1 pseudogout granulation mass, 1 neoplasm	49.3	6/7	1 death, from myocardial infarction
Kassam et al. [23]	Endoscopic transoral approach	1	1 degenerative	73	1/1	None
Husain et al. [21]	Endoscopic transoral approach	11	7 congenital anomalies, 2 trauma, 2 degenerative	27.7	11/11	2 pharyngeal wound dehiscence, 1 immediate postoperative neurological worsening, 2 posterior wall infection
Wolinsky et al. [44]	Endoscopic transcervical approach	3	3 congenital anomalies	61.6	3/3	1 intraoperative CSF leakage
Wu et al. [45]	Endoscopic endonasal approach	3	2 degenerative, 1 traumatic	44	3/3	1 intraoperative CSF leakage
McGirt et al. [28]	Endoscopic transcervical approach	4	4 Congenital anomalies	14	4/4	1 subluxation with Halo vest
Menezes [30]	Transoral approach	280	267 Congenital anomalies, 7 tumors, 6 other	16	280/280	2 pharyngeal wound dehiscence, 5 velopalatine incompetence
Perrini [33]	Transoral approach	34	34 Congenital anomalies	55	32/34	2 dural lacerations, 1 oral wound dehiscence, 2 urinary infections, 2 pulmonary embolisms, 1 pseudoarthrosis, 1 velopharyngeal dysfunction, 4 deep vein thromboses, 2 posterior wound infections, 1 chest infection
El-Sayed et al. [16]	Total Transoral approach (3) Combined endoscopic transnasal and transoral approaches (8)	11	Endoscopic: 2 tumors, 2 infections, 1 degenerative, 3 congenital anomalies; open: 3 degenerative	54	No report	Dysphagia, airway complications

(continued)

Table 2 (continued)

Author	Approach	No. of patients°	Patient disease	Mean age (years)	Associated posterior fusion	Complications
Lee et al. [25]	Endoscopic transnasal approach	4	1 degenerative, 2 congenital anomalies, 2 neoplasms	48	4/4	1 intraoperative CSF leakage
Visocchi et al. [39]	Endoscopic transoral approach	7	3 neoplasms, 1 traumatic, 1 degenerative, 2 congential anomalies	6–78	6/7	None
Salunke et al. [34]	Transoral approach	24	24 congenital anomalies	5–60	15/24	4 prolonged ventilation, 1 CSF leakage, 1 residual compression, 4 pharyngeal wound infections
Dhaliwal et al. [37]	Transoral approach	22	7 neoplasms, 7 congenital anomalies, 6 degenerative	50	19/22	1 spinal cord injury, 1 durotomy, 2 wound complications, 1 hardware failure, 3 prolonged dysphagias, 6 infections, 5 respiratory distress, 2 deep vein thromboses.
Gladi et al. [19]	Endoscopic endonasal approach	4	4 degenerative	74	2/4	None
Dasenbrock et al. [14]	Endoscopic transcervical approach	15	5 degenerative, 9 congenital anomalies	42	15/15	2 urinary tract infections, 2 upper airway swelling, 2 dysphagias, 1 asymptomatic pseudomeningocele
Choi and Crockard [8]	Transoral approach	533	95 congenital anomalies, 216 degenerative, 34 traumatic, 100 tumors, 14 infections, 20 other conditions	46.3	228/533	6 CSF leakages, 11 sepsis, 13 meningitis, 34 infections, 19 cardiovascular complications, 71 respiratory complications, 15 dysphagias, 2 hematomas, 33 velopharyngeal incompetence, 4 cranial nerve palsy, 20 fixation failures, 7 subaxial instability requiring surgery, 5 paralysis, 9 other complications
Hickman et al. [20]	Endoscopic transnasal approach	2	2 congenital anomalies	11–12	2/2	1 incomplete resection of the odontoid process, 1 minimal swallowing impairment
Morales-Valero [29]	Endoscopic transnasal approach	Review	The endoscopic endonasal approach, rather than being considered an alternative, should be considered as a complementary approach to the standard transoral-transpharyngeal route	55.8		CSF leakage; 18 % intraoperative and 4.2 % postoperative; Mortality 1.4 %, transient velopharyngeal insufficency; 2 patients respiratory failure
Gladi [19]	endoscopic transnasal	4	rheumatoid pannus and basilar invagination (BI)		2/4	None
Chaudry [9]	endoscopic transnasal	1	BI and moderate cranial settling	47	No	intermittent mild dysphagia

(continued)

Table 2 (continued)

Author	Approach	No. of patients°	Patient disease	Mean age (years)	Associated posterior fusion	Complications
Ponce-Gomez [34]	Total 5 endoscopic transnasal 7 transoral microsurgical	12	craniovertebral junction instability	18-52	12/12	In 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, and a shorter hospital stay, with no complications in this series
Menezes [15]	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 decompresion, 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 traction; an intraoperative 3D CT scan is obtained in traction. The patient is then placed prone and another 3D CT scan is obtained. The updated algorithm is shown in			Velopharyngeal insufficiency 1.8 % pharyngeal wound dehiscence 0.7 %
Burns et al. [6]	endoscopic transnasal	2	Ventral epidural abscess with osteomyelitis at the craniovertebral junction	69. 55	2/2	CSF leakage

CSF cerebrospinal, *CT* computed tomography, *MRI* magnetic resonance imaging

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.

The Menezes group (Dlouhy et al. [15]) emphasize the importance of intraoperative reduction strategies. 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 posterior fixation. All patients undergo neck flexion/extension magnetic resonance imaging (MRI) of the CVJ. The patient is

positioned supine with halo crown traction; an intraoperative three-dimensional computed tomography (3D CT) scan is obtained in traction. The patient is then placed prone and another 3D CT scan is obtained. The updated algorithm is shown in [13].

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 [43].

The pure endonasal and cervical endoscopic approach deserves consideration, but it still has three disadvantages, the first two being: (1) the steep learning curve and (2) the lack of 3D perception of the surgical field, which could be an operationally limiting factor. Image clarity would 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. The third disadvantage is that there is a limited working channel, depending on 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, this endoscopically assisted transoral approach 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 exist for this approach, compared with the pure endonasal and transcervical approaches to the CVJ, in normal anatomical conditions.

Of note, the endoscope has an interesting role as "support" for the standard transoral microsurgical approach, since 30° angulated endoscopy strongly improves the visual but not the working channel and volume, even though soft palate splitting is often still required. In our opinion, the transoral (microsurgical or video-assisted) approach with sparing of the soft palate still remains the gold standard compared with the "pure" transnasal and transcervical approaches, due to the wider working channel provided by the former technique. The transnasal endoscopic approach alone appears to be superior when the CVJ lesion exceeds the upper limit of the inferior third of the clivus. Furthermore, the combined transnasal and transoral procedures can be tailored according to the specific pathological and radiological findings.

According to a recent anatomical study, the lower incidence of postoperative dysphagia with the endonasal approach is likely related to the lower density of neuronal elements from the pharyngeal plexus above the palatal plane [38].

However, the time to extubation and oral feeding was significantly shorter in the endonasal group in that study. 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 [39].

Finally, to further validate all the endoscopic techniques, experience is required with greater numbers of patients and long-term follow-up. In our opinion, and in agreement with other authors, the endoscopic endonasal approach should be considered a complementary approach, rather than an alternative, to the standard transoral-transpharyngeal route [29].

Conflict of Interest Statement No conflict of interests does exist.

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