Endoscopic Endonasal Approaches to the Craniovertebral Junction: A Systematic Review of the Literature

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Abstract

Keywords

- craniovertebral junction
- endoscopic
- endonasal
- transnasal
- transoral
- cervicomedullary
- craniocervical
- odontoidectomy
- basilar invagination

Background We reviewed the current literature pertaining to extended endoscopic endonasal approaches to the craniovertebral junction.

Methods A systematic literature review was utilized to identify published surgical cases of endoscopic endonasal approaches to the craniovertebral junction. Full-text manuscripts were examined for various measures of surgical indications, patient characteristics, operative technique, and surgical outcomes.

Results We identified 71 cases involving endoscopic endonasal approaches for surgical management of a variety of pathologies located within the craniovertebral junction. Patient ages ranged from 3 to 87 years, with 40 females and 31 males. Five patients required tracheostomy, two were reintubated, and all others experienced an average intubation duration of 0.54 days following surgery. Fifty-eight patients (81.7%) underwent an additional posterior decompression or fusion either before or after the endonasal procedure. A complete resection of the pathologic lesion was reported in 57 cases (83.8%), another five were successful biopsies, and four resulted in partial resection. The follow-up time ranged from 0.5 to 57 months.

Conclusion Although the transoral approach has been the standard for anterior surgical management for the past several decades, our systematic review illustrates that the extended endoscopic endonasal approach is a safe and effective alternative for most pathologies affecting the craniovertebral junction.

Introduction

Several etiologies are known to cause basilar invagination, an anomaly of the craniovertebral junction resulting in odontoid-mediated compression of the brainstem and/or cervicomedullary junction.¹ Surgical intervention in the craniovertebral junction is inherently challenging and has traditionally been accomplished through a transoral resection and subsequent posterior fixation.^{1,2} Transoral resections, despite providing a direct route to the craniovertebral junction, have many disadvantages including increased risk of contamination from oral

flora, damage to structures within the oral cavity and oropharynx, prolonged intubation, and enteral feeding.^{3–5} Transoral resections in pediatric patients may be further complicated by a restricted working area secondary to the small oral cavity in young patients, difficulty with superior resections often requiring splitting of the hard or soft palate, exacerbation of oral palatal dysfunction, and increased risk of airway edema necessitating prolonged intubation.^{6,7} Alternative surgical approaches to the craniocervical junction include the transmandibular, transcervical, combined transoral-transnasal, as well as posterior decompression and fixation.^{8–14}

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Fig. 1 Artistic rendering of the endoscopic endonasal approach to the craniovertebral junction. Reprinted with permission from "Endoscopic endonasal odontoidectomy in a child with chronic type 3 atlantoaxial rotatory fixation: case report and literature review," by Patel AJ, Boatey J, Muns J et al., 2012, *Child's Nervous System*, 28, p. 1974. Copyright 2012 by Springer.

It was not until several anatomical studies examined the feasibility of a purely endonasal approach to the craniocervical junction in cadaveric specimens that a new surgical corridor was brought to the forefront (►Fig. 1).^{15–21} Kassam et al²² were the first to illustrate the accessibility in a patient requiring a decompressive odontoidectomy, further advancing the endonasal approach as a viable alternative to the oral approach. Since these initial studies, the increasing body of literature describing the use of the transnasal approach has shed light both on the intraoperative and postoperative benefits and the limitations associated with this new technique.

In the current study, we present a systematic literature review of both pediatric and adult cases involving endoscopic transnasal approaches to the craniovertebral junction. We identified and quantified several key variables including time to extubation, necessity of tracheostomy or enteral feeding, surgical complications, degree of resection, and degree of atlas structural preservation.

Materials and Methods

Search Strategy and Terms

A systematic literature review was performed to identify all published cases of endoscopic endonasal approaches to the craniovertebral junction. A search for all endoscopic endonasal approaches was performed using the database. Search terms included *endoscopic*, *endonasal*, *craniovertebral junction*, *craniocervical junction*, *cervicomedullary*, *odontoid*, *atlas*, *axis*, *occiput*, *C2*, and *dens*, in various combinations. The search string *endoscopic endonasal* was used as a general search to capture the largest number of possible cases.

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Inclusion/Exclusion Criteria

All articles deemed consistent with endoscopic endonasal approaches to the craniovertebral junction were further analyzed for their sources and references. Exclusion criteria included non-craniovertebral junction pathology, non-English-language manuscripts, cadaveric or radiologic studies, and nonspecific or combined case data. Full manuscripts were predominantly used to evaluate application of the inclusion and exclusion criteria; however, abstracts were used for screening when the full manuscript was not available. For each study, several variables were quantified including number of patients, gender, patient age, diagnosis prior to transnasal resection, use of neuronavigation, time to extubation, need for tracheostomy or enteral feeding, patient length of stay, postoperative complications, degree of resection, degree of C1 arch preservation, and the timing and necessity of additional posterior fusion.

Results

Literature Review

The literature search yielded 186 studies, of which 67 were secondarily assessed based on relevance. From this pool of studies, 23 were included for analysis based on application of the inclusion/exclusion criteria. An additional five studies (Cornelius et al,²³ Grammatica et al,²⁴ Scholtes et al,²⁵ Yu et al,¹ and Gempt et al²⁶) were cited in other studies and included in the selection. A total of 28 studies were selected for the final review and analysis. ►Fig. 2 summarizes the search strategy and results.

►Table 1 summarizes and reviews a total of 71 patient cases from 28 studies. There were 40 females (56.3%) and 31 males (43.6%), with ages ranging from 3 to 87 years (mean age: 45.7 years). Indications for surgery included basilar invagination (43 patients [60.6%]), rheumatoid arthritis with and without pannus formation (23 patients [32.4%]), Chiari malformation (12 patients [16.9%]), atlantoaxial rotatory fixation and subluxation (11 patients [15.5%]), congenital osseous malformation (7 patients [9.9%]), os odontoidum (5 patients [7.0%]), osteogenesis imperfecta (3 patients [4.2%]), metastatic carcinoma (3 patients [4.2%]), Down syndrome (2 patients [2.8%]), osteomyelitis (2 patients [2.8%]), achondroplastic dwarfism (1 patient [1.4%]), cerebral palsy (1 patient [1.4%]), ganglion cyst (1 patient [1.4%]), cat-eye syndrome (1 patient [1.4%]), human T-cell leukemia-lymphoma virus 1 (1 patient [1.4%]), rhabdomyosarcoma (1 patient [1.4%]), osteosarcoma (1 patient [1.4%]), radiation fibrosis (1 patient [1.4%]), and cervical trauma (1 patient [1.4%]). All patients underwent an endoscopic endonasal approach to the craniovertebral junction with the use of either neuronavigation or intraoperative fluoroscopy.

Of the 71 cases, 57 reported respiratory status outcome. Five patients (8.8%) required tracheostomy, and 2 (3.5%)

Fig. 2 Literature search strategy.

required reintubation following surgery. Hickman et al²⁷ reported a patient who was extubated on postoperative day (POD) 1 but immediately underwent tracheostomy due to respiratory arrest. Another patient in this same study required temporary reintubation due to poor initial airway protection. Although one patient in Mazzatenta et al²⁸ required a tracheostomy prior to surgery due to increasing respiratory disturbance secondary to disease progression, this was discontinued immediately following surgery. The patient in Rawal et al²⁹ required a tracheostomy during surgery because significant trismus made orotracheal intubation difficult. Of the remaining cases that reported post-surgical respiratory status that were not complicated by tracheostomy or reintubation ($n = 50$), the mean time of intubation was 0.54 days (range: 0–4 PODs).

In total, 57 cases reported whether or not patients required enteric feeding during the hospital stay. Four patients (7.0%) required nasogastric tube feeding postoperatively, and the duration ranged from 1 to 3 weeks. One patient in the Hickman et al²⁷ study required a gastrostomy tube prior to and following surgery. All other patients ($n = 52$ [91.2%]) did not require enteric feeding and were advanced to an oral diet by POD 5, with most being fed the day after surgery.

Only complications that were a result of the endoscopic endonasal procedure were examined (i.e., complications

resulting from adjunct posterior decompression and fusion were not included). A total of 15 complications were reported. There were eight intraoperative cerebrospinal fluid (CSF) leaks (11.3%) that were all successfully treated with fibrin glue, fat graft, and mucosal flap repair. Beech et al³⁰ and Choudhri et al³¹ each reported a case of velopharyngeal incompetency (2.8%) that resolved within 6 months of surgery. A further two cases of epistaxis, one case of persistent neuropathic pain, and one case of postoperative myocardial infarction were reported. Duntze et al³² reported the only case of postoperative mortality: a patient expired 2 months after surgery secondary to pulmonary embolism.

Fifty-eight patients also underwent an additional posterior or fusion involving the occiput and/or cervical spine. Twenty-seven (46.6%) of these procedures occurred at some point prior to the endoscopic endonasal operation; 26 (44.8%) occurred afterward. All five patients (8.6%) reported in the Ponce-Gómez et al⁴ study required an additional posterior fusion; the time course as to when this procedure occurred, however, was not stated. A total of 13 patients did not require an additional posterior decompression or fusion.

We also examined the relationship between C1 arch preservation and the necessity for additional posterior fusion procedures. Of cases that commented on C1 arch integrity within the operative description ($n = 68$), 51 (75%) partially

Table 1 Endoscopic endonasal procedures: 71 patient cases

Study	Patients, n	Females/ Males	Age of patients, (mean, range)	Diagnosis	Extubation day/ Tracheostomy required	Enteral feeding required	Complications	Additional posterior decompression/Fusion following or prior	C1 arch preservation	Degree of resection/Success rate	Average follow-up time (range, mo)
Kassam et al ²²	1	1/0	73 (73, 73)	RA + BI	POD 1	None	None	Following	No	Complete	1 (1, 1)
Hansen et al ⁴⁵	1	1/0	26 (26, 26)	OI + BI	POD 2	Not mentioned	None	Following	No	Complete	15 (15, 15)
Laufer et al ⁴⁷	1	0/1	25 (25, 25)	Achondroplastic dwarfism + RA + BI	POD 0	Not mentioned	None	Prior	No	Complete	Not mentioned
Magrini et al ⁴⁴	1	0/1	11 (11, 11)	DS + AAS + OD	POD 3	Not mentioned	Intraoperative CSF leak	Prior	No	Complete	2 (2, 2)
Wu et al ⁴⁹	3	0/3	44.3 (33, 59)	RA + BI; RA + BI; cerebellar palsy + BI + AAS	POD 0 × 3	None	Intraoperative CSF leak × 1	Following × 3	No × 3	Complete × 3	2 (range not mentioned)
Leng et al ³⁸	1	1/0	50 (50, 50)	BI + AAS + OD + history of cervical spine injury	POD 1	None	None	Prior	No	Complete	3 (3, 3)
Hankinson et al ⁶	2	1/1	13 (11, 15)	CM + BI; CM + BI	POD 1; Trach POD 2; reintubation	Not mentioned	None	Following × 2	No × 2	Complete × 2	13.5 (9, 18)
Lee et al ³	4	1/3	48.8 (6, 85)	RA + P; metastatic CA; CM + BI telangiectatic osteosarcoma	POD 0 × 3; reintubation × 1	None	Intraoperative CSF leak × 1	Following × 4	No × 4	Not mentioned × 1; complete × 1; partial (biopsy) × 2	6.5 (6, 7) 2 patients not mentioned
Cornelius et al ²³	1	0/1	57 (57, 57)	HTLV-1 + AAS + infiltrating retropharyngeal soft tissue mass	POD 0	Not mentioned	None	Prior	Yes	Complete	Not mentioned
Gempt et al ²⁶	3	3/0	64.3 (52, 77)	RA + BI; retrodental extradural tumor; BI + OD	POD 0 × 3	NGT 21 d × 1 NGT 7 d × 2	None	Prior × 3	No × 2; yes × 1	Complete (s/p 2nd transnasal) × 1; complete × 1	6.3 (3, 12)
Grammatica et al ²⁴	1	0/1	24 (24, 24)	CM + BI	Not mentioned	Not mentioned	None	Following	No	Complete	0.5 (0.5, 0.5)
Scholtes et al ²⁵	1	1/0	45 (45, 45)	CM + BI	POD 0	Not mentioned	None	No	No	Complete	9 (9, 9)
Tomazic et al ⁹	1	1/0	11 (11, 11)	CM + BI	POD 1	None	None	Prior	Unknown	Unknown	12 (12, 12)
Beech et al ³⁰	1	1/0	10 (10, 10)	BI + OD	Not mentioned	Not mentioned	Velopharyngeal incompetency	Following	No	Partial	6 (6, 6)
Gladi et al ²³	4	3/1	74.25 (69, 80)	RA + P; RA + P; BI; BI	POD 2 × 3; POD 1 × 1	None	None	Following × 1; prior × 1; no × 2	Yes × 2; no × 2	Complete × 4	22 (12, 31)
Patel et al ⁷	1	1/0	10 (10, 10)	ARF + BI	POD 0	None	None	Following	No	Complete	7 (7, 7)
Sinha et al ⁸	1	1/0	13 (13, 13)	OI + BI	POD 1	None	None	No	Unknown	Unknown	3 (3, 3)
Hickman et al ²⁷	2	0/2	11.5 (11, 12)	CM + OI + BI; DS + BI + P	Trach × 1; POD 4 × 1	Preexisting gastrostomy × 1	None	Prior × 1; following × 1	No × 1; unknown × 1	Complete (s/p 2nd transnasal) × 1; complete × 1	7 (5, 9)
Iacoangeli et al ⁵⁰	3	2/1	75.3 (70, 80)	RA + BI; RA + P; RA + P	Not mentioned	None	None	No	Yes × 3	Complete × 3	28.3 (20, 40)
Rawal et al ²⁹	1	1/0	66 (66, 66)	BI + radiation fibrosis	Trach	Not mentioned	None	Following	No	Complete	5 (5, 5)
Yu et al ⁵	1	0/1	32 (32, 32)	BI + congenital osseous malformation	POD 0	None	None	Following	No	Complete	12 (12, 12)

(Continued)

Table 1 (Continued)

Study	Patients, n	Females/ Males	Age of patients, (mean, range)	Diagnosis	Extubation day/ Tracheostomy required	Enteral feeding required	Complications	Additional posterior decompression/Fu- sion following or prior	C1 arch preservation	Degree of resec- tion/Success rate	Average follow-up time (range, mo)
Yu et al ¹	3	2/1	51.3 (42, 59)	BI + congenital osse- ous malformation × 3	POD 1 × 3	None	CSF leakage × 1	Following × 2; no × 1	No × 3	Complete × 3	26.7 (24, 30)
Choudhri et al ³¹	5	4/1	67(55, 87)	OM; RA + P; OM; metastatic CA; RA + P	POD 0 × 5	None	Velopharyngeal incompetency × 1	Prior × 5	No × 5; yes × 1	Complete × 4; partial (biopsy) × 1	18.8 (4, 36)
Duntze et al ³²	9	4/5	64 (32, 84)	RA + P; BI; RA + P; RA + P; RA + P; BI; BI; OD	Not mentioned	None	PE + death × 1; persistent neuro- pathic pain × 1; postoperative MI × 1	No × 3; following × 6	No × 3; yes × 6	Complete × 9	(3, 24) average not mentioned
Goldschlager et al ³³	6	4/2	42 (7, 77)	Metastatic CA; CM + BI; ganglion cyst; RA + P + BI; CM + BI + cat-eye syndrome; CM + BI	POD 0 × 5; POD 1 × 1	None	Epistaxis × 2	No × 1; prior × 4; following × 1	No × 5; yes × 1	Complete × 2; partial × 3; partial (biopsy) × 1	42.9 (range not mentioned)
Mazzatenta et al ²⁸	5	3/2	30 (11, 64)	AAS BI + congenital malformation; BI + congenital malforma- tion; AAS BI + con- genital malformation	POD 0 × 3; POD 3 × 1; trach × 1	NGT (duration unknown) × 1	Intraoperative CSF leak × 4	Prior × 5	No × 5; yes × 1	Complete × 5	34.2 (3, 57)
Ponce-Gómez et al ⁴	5	4/1	42.6 (28, 52)	RA + BI; RA + BI; CM + AAS; RA + BI + AAS; AAS + hypopla- sia of basiocciput	POD 0 × 5	None	None	All patients had fu- sion; time course unclear	Yes × 3; no × 2	Complete × 5	6 (6, 6)
Tan et al ⁴⁶	3	0/3	9.3 (3, 13)	CM + BI; BI + AAS; rhabdomyosarcoma	POD 0 × 2; trach × 1	Not mentioned	None	Prior × 2; no × 1	No × 3	Complete × 2; partial (biopsy) × 1	Not mentioned

Abbreviations: AAS, atlantoaxial subluxation; ARF, atlantoaxial rotary fixation; BI, basilar invagination; CA, carcinoma; CM, Chiari malformation; CSF, cerebrospinal fluid; DS, Down syndrome; MI, myocardial infarction; NGT, nasogastric tube feeding; OD, os odontoideum; OI, osteogenesis imperfect; OM, osteomyelitis; P, pannus formation; PE, pulmonary embolism; POD, postoperative day; RA, rheumatoid arthritis; s/p, status post; trach, tracheostomy.

^aTomazic et al 2011 and Sinha et al 2012 were not available through at our institution; all data for these articles were gathered from Hickman et al.²⁷

Note: Multiplicative number indicates number of patients that met that parameter. For example, in Mazzatenta et al²⁸ under extubation day, POD 0 × 3, POD 3 × 1, and Trach × 1 indicate that among the five patients included in the study, three patients were extubated on POD 0, one patient was extubated on POD 3, and 1 patient required tracheostomy.

or completely resected the C1 arch. In 17 cases (25%), the C1 arch was structurally preserved. Of these 17 cases involving C1 arch preservation, 2 cases (11.8%) had already undergone a posterior fusion prior to the endonasal surgery, 3 (17.6%) required a posterior fusion after the endonasal surgery, 3 (17.6%) had additional posterior fusion but did not specify when this occurred in relation to the endonasal procedure, and 9 (53.0%) did not require a posterior fusion at all. Although Goldschlager et al³³ reported a case of C1 arch preservation that did not have an additional posterior fusion, it should be noted that this case was a biopsy procedure.

The degree of surgical resection and overall success rates were also examined. In 68 of the 71 total cases, this measure was reported. In 57 patients (83.8%), a complete resection of the pathologic lesion (odontoid, tumor, etc.) was accomplished. A further two cases, one in Hickman et al²⁷ and another in Gempt et al,²⁶ required a second endoscopic endonasal procedure for complete resection of the lesion. Five patients underwent a successful biopsy, four achieved only a partial resection, and in three cases the degree of resection was not mentioned. Following surgery, all 71 patients in this review showed, at the very least, preservation of neurologic functioning with most exhibiting an improvement. Follow-up time was reported in all but seven cases, ranging from 0.5 to 57 months.

Discussion

A wide variety of pathologies may affect the craniovertebral junction. In this review, the cases reported include rheumatologic disorders, congenital malformations, infections, degenerative disorders, neoplastic diseases, and traumatic injuries, among others. The management of such diseases affecting this uniquely delicate and transitional area of the central nervous system has proved challenging in many regards. Although several surgical approaches have been examined, the recent surge in defining the limitations of endoscopic endonasal approaches has allowed clinicians to directly compare this relatively new technique of the past decade against standard practices, especially that of the microscopic transoral approach.³⁴

The current systematic review highlights the indications and immediate postoperative and perioperative outcomes associated with extended endonasal approaches to the craniovertebral junction. The safety profile associated with the extended endoscopic approach was rather favorable, with very few reported cases of perioperative mortality (1.4%), postoperative CSF leaks (0%), and infections (0%). Avoidance of oropharyngeal incisions and utilization of pedicled mucosal flaps were likely to facilitate the recovery process, resulting in few patients with long-term requirements for intubation, tracheostomy, or nutritional assistance.

The most distinct advantage of the purely endonasal approach over the traditional transoral procedure involves the use of the endoscope. Aside from a few studies that have used endoscopy or a surgical robot system as part of the transoral approach, the mainstay has been to use the operating microscope.^{13,24,34–37} However, endoscopy is an

integral component for access gained through the nasal cavity and provides a panoramic view, higher resolution, and closer light source, all enhancing the quality of the visual field.^{3,4,17,38} Moreover, with the use of intraoperative navigation, the combination enhances the detail of the surgical view that directly translates to the degree of potential resection.³¹ Hickman et al²⁷ describe the first incidence of reoperation after an endonasal approach and suggest one contributing factor as the failure of the intraoperative navigation system, further highlighting the importance of this technology.²⁷ Indeed, of the 71 total cases examined in this review, the vast majority incorporated a navigation system in the operative setting.

The choice of the most feasible approach is fundamentally based on the location of the targeted structure relative to the surgical opening. By avoiding skin incisions used in the transcervical and posterior approach, both the transoral and transnasal approaches emphasize a minimally invasive nature of the operation by entering through natural anatomical orifices and corridors. Accessibility to the targeted region, however, is often complicated by certain structures of these natural surgical corridors. For example, by going through the nasal cavity, the transnasal approach is limited superiorly by the nasal bone and inferiorly by the hard palate.¹⁸ Several radiographic studies have established anatomical lines between structures within these corridors to accurately predict the accessibility to the ventral spine. Initially, the nasopalatine line (NPL) was used by drawing a line from the rhinion through posterior edge of the hard palate and extending to the vertebral column. In doing so, it was believed that this line could represent the steepest angled trajectory of the endoscope in an attempt to reach the most inferior aspect possible through this route.³⁹ Studies using the NPL suggested that although the transnasal approach allow direct access to higher structures such as the clivus and odontoid, it cannot reliably reach inferiorly beyond the base of C2.^{4,16,39} Aldana et al, however, found that the NPL overestimated this inferior limit capable with the endonasal approach because the rhinion is superior to the nares, which represents the actual structure limiting the superior movement of the endoscope. They proposed the naso-axial line (NAXL) that utilizes a more inferior starting point midway between the rhinion and the anterior nasal spine. The NAXL predicted an inferior limit no further than the upper half C2 and was found to be no different from the actual point achieved through endonasal dissection in cadaveric specimens. The NPL, however, predicted the limit to reach the lower half of C2, and it was significantly different from the actual surgical limit by a mean of 12.7 mm.⁴⁰

In contrast, the anatomy of the oral cavity, bordered by the soft and hard palate superiorly and tongue inferiorly, allows for this inferior limit to include C3—possibly further with more invasive interventions such as glossotomy or mandibulotomy.¹⁶ Yet the trajectory of the transoral approach makes it difficult to reach superior structures within the craniovertebral junction such as the tip of the odontoid. In cases of transoral odontoidectomy, it is not uncommon for the surgeon to split the soft and hard palate to extend access in the

superior direction. Consequently, this can result in velopharyngeal insufficiency (VPI) and a disturbance in phonation.^{2,30,41,42} A comprehensive systematic review of transoral odontoidectomies by Komotar et al⁴³ reported that 88 of 262 cases (36.2%) incorporated an incision in the soft palate, and 14 of 351 cases (4.0%) resulted in VPI. This complication is rare in the endonasal approach. In all the cases ($n = 71$) examined, not a single patient underwent a soft or hard palate resection, and only two cases of VPI were found in the literature, both of which resolved within 6 months. The ability to access the craniovertebral junction through these direct and natural corridors without splitting the palate again illustrates a major benefit of endonasal surgery over the transoral approach.

Characteristics of the natural apertures itself can also prove to be a limiting factor to the operation. For example, in the pediatric population the smaller opening to the oral cavity can certainly reduce the extent of the surgical trajectory. This is further complicated by certain pathology such as micrognathia, macroglossia, midface hypoplasia, as well as large body habitus, each of which can minimize the accessibility through the oral cavity.^{7,27,38,44,45} Endonasal procedures can also have limitations. Manipulation of instruments within the nasal cavity can be hindered by the middle and inferior turbinates in addition to the nasal septum.^{3,4,15,22,46} Although it is possible to resect these structures during the course of the surgery, such interventions can result in disturbances to the normal laminar airflow during respiration. Such defects can in turn lead to nasal crusting and increased rates of upper airway infections.⁴⁷

In addition to accessibility, several other advantages of the endoscopic endonasal approach exist over other procedures. Endonasal approaches use a smaller incision located along the posterior wall of the nasopharynx. In contrast, the transoral approach places the incision along the oropharyngeal mucosa. The more caudal placement of transoral dissection exposes the incision to saliva and contamination by oral flora that is otherwise minimized in the endonasal approach.^{4,42,48–50} In our analysis, we did not encounter a single case of postoperative infection as a result of endonasal surgery—however, several instances of postoperative infections resulting from the subsequent posterior decompression and fusion procedures were identified.

Moreover, unlike the endonasal approach, transoral procedures require retraction within the oral cavity that can lead to soft tissue swelling of the tongue and retropharyngeal mucosa.^{8,10,16,25} This, in turn, necessitates airway protection and prolonged intubation following surgery—in some cases even resulting in tracheostomy. Our analysis found that patients were extubated by POD 4 with most extubated the day of surgery. Five cases (8.8%) required tracheostomy. Although use of tracheostomy has been reported as low as 3.8% in transoral studies, it should be noted that in our endonasal analysis, three of the five tracheostomy cases were due to factors unrelated to injury resulting from the procedure. One case was due to early extubation and oversedation, another due to preoperative tracheostomy needed for disease-induced respiratory failure that was discontinued

immediately after anesthesia, and the last case attributed to trismus that made intubation challenging.⁴³ Oropharyngeal compromise has a similar effect in terms of feeding. Only four of the cases previously reported required nasogastric tube feedings, whereas all other patients were advanced to an oral diet within the first 5 days following surgery. With both decreased time of intubation and rapid advancement of diet, the transnasal approach provides faster recovery time and is likely to be associated with a shorter hospital stay. Although fewer than half of the cases reported actual in-hospital recovery time, those studies that did mention this parameter mostly reported discharge within 1 week of surgery.

Another variable we examined in this review was the incorporation of a posterior fusion involving the occiput and/or cervical spine in addition to the ventral procedure. Several biomechanical studies have suggested the significance of the C1 arch in cervical stability.^{16,51–53} With the loss of C1 arch integrity, there is an increased risk of secondary craniocervical dislocation under the pressure exerted by the weight of the head as well as torque from lateral rotational movements.^{3,32,50} Of the 17 cases that involved an endonasal surgical resection with C1 arch preservation, 9 (53.0%) did not require additional fixation. Several cases reviewed here report an obliquely angled advancement of instrumentation so as to pass over the C1 arch and successfully perform a partial odontoidectomy.^{32,53} In doing so, their patients were free of additional surgical interventions, and on follow-up, none exhibited evidence of cervical instability. Not only does this add to the growing literature of endonasal procedures to the craniovertebral junction, it also lends support to the feasibility of a single-stage anterior decompression.

One of the major criticisms of endoscopic endonasal approaches relates to management of major intraoperative complications—namely vascular injury and CSF leaks. In the event of vascular compromise during the operation, including injury to the internal carotid arteries (ICAs), the pooled blood can quickly obscure the surgical view through the endoscope. Rapid introduction of appropriate instruments in this setting can be difficult, and adequate hemostasis may be challenging. Fortunately, instances of major intraoperative bleeding during endonasal approaches are rare, and to our knowledge only one case of an accidental tear of the ICA has been reported, and it was successfully repaired with no long-term sequelae.⁵⁴ Much more common than the rare incidence of carotid artery injury is the risk for intra- and postoperative CSF leaks and secondary infections resulting in meningitis.^{31,32} We report an intraoperative CSF leak rate of 11.3% (8 of 71 cases). In every case, a piece of fat graft from the abdominal wall was placed inside the operative cavity overlying the dural defect.^{1,3,28,44,49} Following this initial step, a fibrin sealant was used, and the nasopharyngeal mucosal flap created at the start of the operation was returned to its original position. In five of the eight cases this mucosal flap was anchored to the surrounding tissue with silk sutures; the remaining three cases used fibrin glue to seal the edges. Although all leaks were successfully repaired without postoperative complications, it does demonstrate the potential for a major CSF fistula in this region.^{4,44,49} Primary dural closure with sutures

remains unrealistic and thereby limits the applicability of the endonasal approach for intradural lesions. This issue, however, is also encountered in the other approaches; the incidence of postoperative CSF leaks following transoral odontoidectomies was 5.5% (8 of 145 cases).⁴³ The occurrence of these complications underscores the importance of the surgeons' familiarity with endoscopy and planning a methodology for repair of complex CSF leaks that have the potential to complicate the endonasal approach.

The current review is subject to several major limitations. The most obvious includes the potential for publication bias among the articles identified and included. The lack of postoperative CSF leaks in the current series and the low incidence of surgical mortality or major morbidity further underscore this issue. Extended endonasal approaches to the craniocervical junction are inherently challenging cases that most neurosurgeons remain unfamiliar with, and they are often necessitated in patients with significant neurologic issues. Additional limitations include the fact that much of the accrued data was acquired from case reports or small case series. Nevertheless, this review can serve as a potentially useful and valid overview of the indications, limitations, and complications of extended endonasal approaches to the craniocervical junction.

Conclusions

Over the past decade, clinicians performing the endoscopic endonasal approach have provided much needed evidence for the feasibility of this procedure as an alternative to more traditional transoral approaches. Especially for lesions above C2, patients who have undergone the endonasal approach have experienced excellent outcomes in terms of relatively short intubation periods, an early return to an oral diet, and minimal complications without lasting sequelae. Furthermore, increasing understanding from biomechanical, anatomical, and radiographic studies has allowed for advancement in operative techniques to achieve superior outcomes, such as increased cervical stability through C1 arch preservation. With this systematic literature review, we hope to provide the most comprehensive analysis on the endonasal approach to date, and in doing so, to underscore the safety and efficacy of this surgical approach for management of the innumerable pathologies that involve the craniovertebral junction.

References

- Yu Y, Wang X, Zhang X, et al. Endoscopic transnasal odontoidectomy to treat basilar invagination with congenital osseous malformations. *Eur Spine J* 2013;22(5):1127–1136
- Menezes AH, VanGilder JC. Transoral-transpharyngeal approach to the anterior craniocervical junction. Ten-year experience with 72 patients. *J Neurosurg* 1988;69(6):895–903
- Lee A, Sommer D, Reddy K, Murty N, Gunnarsson T. Endoscopic transnasal approach to the craniocervical junction. *Skull Base* 2010;20(3):199–205
- Ponce-Gómez JA, Ortega-Porcayo LA, Soriano-Barón HE, et al. Evolution from microscopic transoral to endoscopic endonasal odontoidectomy. *Neurosurg Focus* 2014;37(4):E15
- Yu Y, Hu F, Zhang X, Ge J, Sun C. Endoscopic transnasal odontoidectomy combined with posterior reduction to treat basilar invagination: technical note. *J Neurosurg Spine* 2013;19(5):637–643
- Hankinson TC, Grunstein E, Gardner P, Spinks TJ, Anderson RC. Transnasal odontoid resection followed by posterior decompression and occipitocervical fusion in children with Chiari malformation Type I and ventral brainstem compression. *J Neurosurg Pediatr* 2010;5(6):549–553
- Patel AJ, Boatey J, Muns J, et al. Endoscopic endonasal odontoidectomy in a child with chronic type 3 atlantoaxial rotatory fixation: case report and literature review. *Childs Nerv Syst* 2012;28(11):1971–1975
- Arbit E, Patterson RH Jr. Combined transoral and median labio-mandibular glossectomy approach to the upper cervical spine. *Neurosurgery* 1981;8(6):672–674
- Delgado TE, Garrido E, Harwick RD. Labiomandibular, transoral approach to chordomas in the clivus and upper cervical spine. *Neurosurgery* 1981;8(6):675–679
- Kanamori Y, Miyamoto K, Hosoe H, Fujitsuka H, Tatematsu N, Shimizu K. Transoral approach using the mandibular osteotomy for atlantoaxial vertical subluxation in juvenile rheumatoid arthritis associated with mandibular micrognathia. *J Spinal Disord Tech* 2003;16(2):221–224
- McGirt MJ, Attenello FJ, Sciubba DM, Gokaslan ZL, Wolinsky JP. Endoscopic transcervical odontoidectomy for pediatric basilar invagination and cranial settling. Report of 4 cases. *J Neurosurg Pediatr* 2008;1(4):337–342
- Sciubba DM, Garonzik IM, Suk I, et al. Frameless stereotaxy in a transmandibular, circumglossal, retropharyngeal cervical decompression in a Klippel-Feil patient: technical note. *Eur Spine J* 2006;15(8):1286–1291
- Wolinsky JP, Sciubba DM, Suk I, Gokaslan ZL. Endoscopic image-guided odontoidectomy for decompression of basilar invagination via a standard anterior cervical approach. Technical note. *J Neurosurg Spine* 2007;6(2):184–191
- Deopujari CE, Karmarkar VS, Shah NJ. Endoscopic approaches to the craniovertebral junction and odontoid process. *World Neurosurg* 2014;82(6, Suppl):S49–S53
- Alfieri A, Jho HD, Tschabitscher M. Endoscopic endonasal approach to the ventral cranio-cervical junction: anatomical study. *Acta Neurochir (Wien)* 2002;144(3):219–225; discussion 225
- Baird CJ, Conway JE, Sciubba DM, Prevedello DM, Quiñones-Hinojosa A, Kassam AB. Radiographic and anatomic basis of endoscopic anterior craniocervical decompression: a comparison of endonasal, transoral, and transcervical approaches. *Neurosurgery* 2009;65(6, Suppl):158–163; discussion 63–64
- Cavallo LM, Cappabianca P, Messina A, et al. The extended endoscopic endonasal approach to the clivus and cranio-vertebral junction: anatomical study. *Childs Nerv Syst* 2007;23(6):665–671
- Messina A, Bruno MC, Decq P, et al. Pure endoscopic endonasal odontoidectomy: anatomical study. *Neurosurg Rev* 2007;30(3):189–194; discussion 194
- Tanriverdi O, Tugcu B, Gunaldi O, et al. The selective odontoidectomy: endoscopic endonasal approach to the craniocervical junction. *J Craniofac Surg* 2014;25(4):1482–1487
- Cavallo LM, Messina A, Cappabianca P, et al. Endoscopic endonasal surgery of the midline skull base: anatomical study and clinical considerations. *Neurosurg Focus* 2005;19(1):E2
- Visocchi M, La Rocca G, Della Pepa GM, et al. Anterior video-assisted approach to the craniovertebral junction: transnasal or transoral? A cadaver study. *Acta Neurochir (Wien)* 2014;156(2):285–292
- Kassam AB, Snyderman C, Gardner P, Carrau R, Spiro R. The expanded endonasal approach: a fully endoscopic transnasal approach and resection of the odontoid process: technical case report. *Neurosurgery* 2005;57(1, Suppl):E213; discussion E213

- 23 Cornelius JF, Kania R, Bostelmann R, Herman P, George B. Transnasal endoscopic odontoidectomy after occipito-cervical fusion during the same operative setting—technical note. *Neurosurg Rev* 2011;34(1):115–121
- 24 Grammatica A, Bonali M, Ruscitti F, et al. Transnasal endoscopic removal of malformation of the odontoid process in a patient with type I Arnold-Chiari malformation: a case report. *Acta Otorhinolaryngol Ital* 2011;31(4):248–252
- 25 Scholtes F, Signorelli F, McLaughlin N, Lavigne F, Bojanowski MW. Endoscopic endonasal resection of the odontoid process as a standalone decompressive procedure for basilar invagination in Chiari type I malformation. *Minim Invasive Neurosurg* 2011;54(4):179–182
- 26 Gempt J, Lehmberg J, Grams AE, Berends L, Meyer B, Stoffel M. Endoscopic transnasal resection of the odontoid: case series and clinical course. *Eur Spine J* 2011;20(4):661–666
- 27 Hickman ZL, McDowell MM, Barton SM, Sussman ES, Grunstein E, Anderson RC. Transnasal endoscopic approach to the pediatric craniovertebral junction and rostral cervical spine: case series and literature review. *Neurosurg Focus* 2013;35(2):E14
- 28 Mazzatenta D, Zoli M, Mascari C, Pasquini E, Frank G. Endoscopic endonasal odontoidectomy: clinical series. *Spine* 2014;39(10):846–853
- 29 Rawal RB, Shah RN, Zanation AM. Endonasal odontoidectomy for basilar impression and brainstem compression due to radiation fibrosis. *Laryngoscope* 2013;123(3):584–587
- 30 Beech TJ, McDermott AL, Kay AD, Ahmed SK. Endoscopic endonasal resection of the odontoid peg—case report and literature review. *Childs Nerv Syst* 2012;28(10):1795–1799
- 31 Choudhri O, Mindea SA, Feroze A, Soudry E, Chang SD, Nayak JV. Experience with intraoperative navigation and imaging during endoscopic transnasal spinal approaches to the foramen magnum and odontoid. *Neurosurg Focus* 2014;36(3):E4
- 32 Duntze J, Eap C, Kleiber JC, et al. Advantages and limitations of endoscopic endonasal odontoidectomy. A series of nine cases. *Orthop Traumatol Surg Res* 2014;100(7):775–778
- 33 Goldschlager T, Härtl R, Greenfield JP, Anand VK, Schwartz TH. The endoscopic endonasal approach to the odontoid and its impact on early extubation and feeding. *J Neurosurg* 2015;122(3):511–518
- 34 Visocchi M, Della Pepa GM, Doglietto F, Esposito G, La Rocca G, Massimi L. Video-assisted microsurgical transoral approach to the craniovertebral junction: personal experience in childhood. *Childs Nerv Syst* 2011;27(5):825–831
- 35 Frempong-Boadu AK, Faunce WA, Fessler RG. Endoscopically assisted transoral-transpharyngeal approach to the craniovertebral junction. *Neurosurgery* 2002;51(5, Suppl):S60–S66
- 36 Yadav YR, Madharia SN, Parihar VS, et al. Endoscopic transoral excision of odontoid process in irreducible atlantoaxial dislocation: our experience of 34 patients. *J Neurol Surg A Cent Eur Neurosurg* 2013;74(3):162–167
- 37 Qiuhan Z, Feng K, Bo Y, et al. Transoral endoscopic odontoidectomy to decompress the cervicomedullary junction. *Spine* 2013;38(14):E901–E906
- 38 Leng LZ, Anand VK, Härtl R, Schwartz TH. Endonasal endoscopic resection of an os odontoides to decompress the cervicomedullary junction: a minimal access surgical technique. *Spine* 2009;34(4):E139–E143
- 39 de Almeida JR, Zanation AM, Snyderman CH, et al. Defining the nasopalatine line: the limit for endonasal surgery of the spine. *Laryngoscope* 2009;119(2):239–244
- 40 Aldana PR, Naseri I, La Corte E. The naso-axial line: a new method of accurately predicting the inferior limit of the endoscopic endonasal approach to the craniovertebral junction. *Neurosurgery* 2012;71(2, Suppl Operative):ons308–ons314; discussion ons314
- 41 Cantarella G, Mazzola RF, Benincasa A. A possible sequela of transoral approach to the upper cervical spine. Velopharyngeal incompetence. *J Neurosurg Sci* 1998;42(1):51–55
- 42 Crockard HA. Transoral surgery: some lessons learned. *Br J Neurosurg* 1995;9(3):283–293
- 43 Komotar RJ, Starke RM, Raper D, et al. Endonasal endoscopic versus transoral microscopic odontoid resection. *Innovative Neurosurg* 2013;1:37–47
- 44 Magrini S, Pasquini E, Mazzatenta D, Mascari C, Galassi E, Frank G. Endoscopic endonasal odontoidectomy in a patient affected by Down syndrome: technical case report. *Neurosurgery* 2008;63(2):E373–E374; discussion E374
- 45 Hansen MA, da Cruz MJ, Owler BK. Endoscopic transnasal decompression for management of basilar invagination in osteogenesis imperfecta. *J Neurosurg Spine* 2008;9(4):354–357
- 46 Tan SH, Ganesan D, Prepageran N, Waran V. A minimally invasive endoscopic transnasal approach to the craniovertebral junction in the paediatric population. *Eur Arch Otorhinolaryngol* 2014;271(11):3101–3105
- 47 Laufer I, Greenfield JP, Anand VK, Härtl R, Schwartz TH. Endonasal endoscopic resection of the odontoid process in a nonachondroplastic dwarf with juvenile rheumatoid arthritis: feasibility of the approach and utility of the intraoperative Iso-C three-dimensional navigation. Case report. *J Neurosurg Spine* 2008;8(4):376–380
- 48 Choi D, Gleeson M. Surgery for chordomas of the craniocervical junction: lessons learned. *Skull Base* 2010;20(1):41–45
- 49 Wu JC, Huang WC, Cheng H, et al. Endoscopic transnasal transclival odontoidectomy: a new approach to decompression: technical case report. *Neurosurgery* 2008;63(1, Suppl 1):ONSE92–4; discussion E94
- 50 Iacoangeli M, Gladi M, Alvaro L, Di Rienzo A, Specchia N, Scerrati M. Endoscopic endonasal odontoidectomy with anterior C1 arch preservation in elderly patients affected by rheumatoid arthritis. *Spine J* 2013;23(5):542–548
- 51 Dickman CA, Crawford NR, Brantley AG, Sonntag VK. Biomechanical effects of transoral odontoidectomy. *Neurosurgery* 1995;36(6):1146–1152; discussion 1152–1153
- 52 Naderi S, Crawford NR, Melton MS, Sonntag VK, Dickman CA. Biomechanical analysis of cranial settling after transoral odontoidectomy. *Neurosurg Focus* 1999;6(6):e7
- 53 Gladi M, Iacoangeli M, Specchia N, et al. Endoscopic transnasal odontoid resection to decompress the bulbo-medullary junction: a reliable anterior minimally invasive technique without posterior fusion. *Eur Spine J* 2012;21(Suppl 1):S55–S60
- 54 Iacoangeli M, Di Rienzo A, Re M, et al. Endoscopic endonasal approach for the treatment of a large clival giant cell tumor complicated by an intraoperative internal carotid artery rupture. *Cancer Manag Res* 2013;5:21–24