Endoscopic Endonasal Approach to the Infraorbital Nerve with Nasolacrimal Duct Preservation

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Abstract

Objectives Infraorbital nerve (ION) decompression, excision to remove intrinsic tumors, and resection with oncological margins in malignancies with perineural invasion or dissemination are usually accomplished with an open approach. The objective is to describe the surgical anatomy, technique, and indications of the endonasal endoscopic approach (EEA) to the ION with nasolacrimal duct preservation.

Design Eleven sides of formalin-fixed specimens were dissected. An anterior maxillary antrostomy was performed. The length of the ION prominence within the sinus and anatomic features of the covering bone were studied. A 45-degree endoscope visualized the infraorbital prominence endonasally. An angled dissector and dural blade allowed for dissection and resection of the ION ipsilaterally and contralaterally.

Results The bone features of the ION prominence allowed for ipsilateral dissection in 10 out of 11 sides. In one case with the ION surrounded by thick cortical bone, the dissection could only be started by drilling contralaterally. The 45-degree endoscope visualized 92.2% and 100% of the length of the nerve using the ipsilateral and contralateral nostrils, respectively. Ipsilaterally, 83% of its length was resected, and 96.3% was resected contralaterally.

Conclusion The ION can be approached using an ipsilateral EEA with nasolacrimal duct preservation in most cases. The contralateral approach provides a wider angle to access the ION. This technique is primarily indicated in cases where the EEA can be used for tumor resection and oncological margins within the ION.

Keywords

- infraorbital nerve
- endoscopic endonasal approach
- maxillary sinus
- infraorbital nerve decompression
- Caldwell-Luc

Introduction

The infraorbital nerve (ION) is the terminal branch of the maxillary nerve (second division of the trigeminal nerve).¹

The ION is located in the roof of the maxillary sinus and can be accessed with an open sublabial approach (Caldwell-Luc) or endonasal approach.^{2–5} Certain skin or, less frequently,

sinonasal malignancies can present with perineural invasion or dissemination and require resection of the ION with oncological margins, usually via an open Caldwell-Luc approach. In case of skin malignancies with perineural spread through the ION, resection of the skin tumor with affected cutaneous branches would provide direct access to the IO foramen and to the ION through the anterior wall of the

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Fig. 1 Anatomy of the infraorbital nerve (ION) and surrounding structures, frontal view. (A) Osseous structures surrounding the ION from the inferior orbital fissure to the infraorbital (IO) foramen, formed by the IO groove proximally and IO canal distally in most specimens. (B) Dissection of the ION and IO artery at its exit through the IO foramen after removal of the skin, subcutaneous tissue, and muscles. (C) A maxillary sinus antrostomy was used to perform measurements leaving a 2-mm rim of bone surrounding the ION. Note the nasolacrimal duct medially. An endoscopic medial antrostomy was performed with limits in the posterior wall of the maxillary sinus posteriorly and the posterior wall of the nasolacrimal duct anteriorly. Measurements of the distance from the ION to the nasolacrimal duct (1) and of the antrostomy width (2) were performed. Inf. orb. fiss., inferior orbital fissure; Sup. Orb. Fiss., superior orbital fissure.

maxillary sinus. In such cases, the endoscopic endonasal approach (EEA) provides access to the skull base margin of the nerve with improved visualization. With sinonasal tumors, where the EEA is used to resect the tumor from the nasal cavity and maxillary sinus, endoscopic endonasal excision of the ION could be considered, avoiding an additional anterior (Caldwell-Luc) or anteromedial (Denker) maxillectomy with a sublabial incision. Surgical decompression of the ION for neuropathies or ION excision to remove intrinsic tumors could be also performed with an EEA.^{6–15}

The aim of this study is to describe and analyze the surgical anatomy, technique, and indications of the EEA to the ION with nasolacrimal duct preservation.

Materials and Methods

Eleven sides of seven formalin-fixed and silicone-injected specimens were used for the dissections.

An anterior maxillary antrostomy through a Caldwell-Luc approach was performed, leaving 2 mm of bone surrounding the infraorbital (IO) foramen (►Fig. 1). All maxillary sinus mucosa was removed, exposing the IO prominence that represents the endoscopic view of the IO groove and canal in the roof of maxillary sinus. A 2-mm opening from the maxillary sinus to the nasal cavity just posterior to the nasolacrimal duct in the middle part of its exposure was performed. That opening marked the anterior limit for the endoscopic maxillary antrostomy to preserve the nasolacrimal duct. The following measurements were performed through the open antrostomy (mm): total length of the ION prominence from the posterior wall of the maxillary sinus to the IO foramen and the distance from the medial aspect of the IO foramen to the lateral aspect of the nasolacrimal duct in the coronal plane (►Fig. 1, ►Table 1). The bone underlying the ION was carefully palpated with a dissector. Any area of dehiscence was identified. The bone was considered paper-

Table 1 Measurements of the ION in the specimens in mm

Sp	Prom.	Dehis.	Thin	Thick	Antr.	ION-N	V1n	V2n	D1n	D2n
1	30	4	21	9	36	8	30	30	30	30
2	28	0	25	3	28	11	20	28	17	27
3	28	0	26	2	26	9	26	28	19	27
4	20	0	0	20	23	13	18	20	0	16
5	30	3	25	5	28	12	26	30	21	25
6	25	1	20	4	25	8	25	25	21	21
7	28	0	25	3	28	10	25	28	25	27
8	24	4	24	0	27	7	24	24	24	24
9	26	6	20	6	27	5	26	26	26	26
10	32	5	23	4	27	9	32	32	32	32
11	25	11	14	8	23	4	21	25	21	25

Abbreviations: Antr., distance from the posterior wall of the maxillary sinus to the posterior aspect of the nasolacrimal duct in the middle part of the antrostomy; D1n, length of the infraorbital nerve (ION) that that can be dissected from the ipsilateral nostril; D2n, length of the ION that that can be dissected from the contralateral nostril; Dehis., length of the dehiscence bone area; ION-N, distance from the medial part of the infraorbital (IO) foramen to the lateral aspect of the nasolacrimal duct; Prom., length of the ION prominence in the maxillary sinus; Sp., specimen side; Thick, length of the thick bone of the prominence; Thin, length of the paper-thin bone segment; V1n, length of the ION prominence that can be visualized from the ipsilateral nostril; V2n, length of the ION prominence that can be visualized from the contralateral nostril.

thin type when it was translucent and could be easily depressed with gentle palpation; otherwise, it was considered thick type. The length of segments of dehiscence, paper-thin bone, or thick bone was also measured.

Before starting the endoscopic endonasal dissection, the soft tissue of the cheek was placed in the anatomical position covering the anterior maxillary antrostomy. Under visualization with a 0-degree endoscope (4 mm, Karl Storz, Tuttlingen, Germany), middle turbinectomy, ethmoidectomy, and wide maxillary antrostomy were performed. The antrostomy was performed from the posterior wall of the maxillary sinus to the posterior aspect of the nasolacrimal duct and from the orbital floor to the superior limit of the inferior turbinate. In all specimens, posterior septectomy to the anterior limit of the maxillary antrostomy was performed. The maximum length of the endoscopic antrostomy was measured through the anterior antrostomy.

A 45-degree endoscope (4 mm, Karl Storz) was used for visualization of the ION prominence in the roof of the maxillary sinus from the ipsilateral and contralateral nostril. The length of visualization of the ION was measured from the posterior part of the prominence in the posterior wall of the maxillary sinus to the most anterior aspect of the nerve visualized.

Dissection of the ION was then initiated. Working from the ipsilateral nostril, an angled ball probe dissector (Karl Storz, ▶Fig. 2) was used to fracture and remove the bony layer covering the ION prominence. Bone removal started at the level of the posterior wall of the maxillary sinus and progressed anteriorly toward the anterior wall to expose the ION and artery. In case of thick bone, a high-speed diamond drill (Stryker, Kalamazoo, Michigan, USA) was used to thin the bone. Once maximum exposure of the ION and artery was achieved working through the ipsilateral nostril, the instruments and the endoscope were placed in the contralateral side to assess if more anterior exposure was possible working in that side. Maximum ION exposure from the ipsilateral and contralateral nostrils was measured. The position of the distal third of the IO artery was also verified. For the nerve transection, an endoscopic dural blade previously bent to simulate the same angle of the ball probe dissector was used. The blade was bent 45 degrees in the distal 20 mm and 85 degrees at the tip (▶Fig. 2). The angled blade was used for transection of the nerve and the artery distally and proximally at the limits of prior exposure.

Results

On average, the ION prominence measured 26.9 mm (range 20 to 32 mm) in length and the IO foramen was located 8.7 mm lateral to the nasolacrimal duct (range 4 to 13 mm) (▶Table 1). A wide medial antrostomy of 27.1 mm on average (range 26 to 36 mm) from the posterior wall of the maxillary sinus to the posterior wall of the nasolacrimal duct was performed under endoscopic visualization (▶Fig. 1). Three features of the bone underlying the ION groove and canal could be distinguished. The most common

Fig. 2 Tools used to perform the infraorbital nerve (ION) dissection from left to right: ball probe; bent blade mimicking the angulation of the ball probe 45 degrees in the distal 20 mm and the tip bent 85 degrees; original blade, note the concavity of the tip that has to be faced down toward the side of the dissection.

type was paper-thin bone in 91% of the specimen sides with some dehiscence parts in most of them (63.6%, 7 dehiscence out of 11). The bone increased in thickness distally when the nerve approached the IO foramen and formed the canal. These characteristics allowed for the endoscopic dissection with the ball probe. It was less frequent (1 out of 11 sides) that the IO groove and canal were formed completely by thick cortical bone, and thus the dissection of the nerve could only be started by drilling (▶Fig. 3). In this specimen, a paper-thin bone type with dehiscence areas was found in the ION of the other side.

The position of the artery in relation to the nerve in the distal third was medial and superior in 64% of the cases and lateral and superior in 36% of the cases.

The 45-degree endoscope allowed for visualization of 92.2% (range 71 to 100%) of the length of the nerve from the ipsilateral nostril. From the contralateral nostril, the endoscopic view of the ION was 100% in all the specimens (▶Fig. 4).

In specimens with thin bone, 83% (range 60 to 100%) of the length of the nerve was resectable from the ipsilateral nostril, leaving 4.8 mm on average of the nerve distally (range 0 to 11 mm). A complete resection was achieved in 4 out of 10 cases. From the contralateral nostril, 96.3% (range 84 to 100%) of the nerve was resectable with 1 mm left distally (range 0 to 5 mm) (▶Fig. 5, ▶Table 1), achieving complete resection in five cases. In the only specimen (1 out of 11 ION) with thick bone, the drill had enough working angle only from the contralateral nostril and the dissection was 80% of the length of the nerve.

Fig. 3 Endoscopic anatomy of different infraorbital nerve (ION) prominences (left side). (A) 91% of the prominences have paper-thin bone underlying the ION and most of them also have a dehiscent part. (B) 9% of the prominences are formed by cortical bone that requires drilling, adding difficulty to the endoscopic dissection.

Discussion

To our knowledge, there are no previous anatomical reports about the feasibility and safety of the EEA for surgery of the ION. Several studies have been performed regarding the endoscopic approach to the maxillary nerve in the pterygo-palatine fossa,^{16–18} as well as detailed descriptive anatomy and variations of the IO canal, groove, and foramen.^{19–25} According to our anatomical study, in most cases the thickness of the bone underlying the ION is favorable for endonasal dissection with a 45-degree endoscope and a ball probe dissector. The ball probe dissector due to its angulation is essential to perform the dissection of the ION. The bone underlying the ION was removed starting at areas of dehiscence or thin bone. The blade has to mimic the angled dissector's shape and its tip needs to have the concavity of the blade faced down toward the dissection side so the bending will be different to dissect the right or left side (►Figs. 2 and 5). The contralateral approach provided a better visualization and dissection of the ION. However, working in the contralateral nostril requires significant resection of the posterior septum or a septotomy to permit the passage of the

instruments from one nasal cavity to the other. In case of thick bone covering the ION, a contralateral approach is required for drilling or other instrumentation. In such cases a classical open approach should be considered. As the thickness of the bone of the ION prominence increases distally, the average dissected length of the nerve is less than the visualization length. The distal part of the bone is the hardest to fracture because of the thickness of the bone and the unfavorable angle for dissection. These features can be preoperatively assessed with a coronal computed tomography (CT) scan that allows for visualization of the bone surrounding the ION.

The IO artery can also be preserved during the dissection using the ball probe to dissect the artery from the nerve, as illustrated in ►Fig. 5B. However, complete visualization of the canal can only be accomplished by dissection and resection of the artery. As the middle and anterior superior alveolar nerves arise from the lateral part of the ION in the IO canal, small nervous filaments can easily remain during the dissection in the superior and lateral part of the canal covered by a preserved artery medially. This is of importance regarding oncological margins. Another aspect is the possibility of intraoperative bleeding of the IO artery or some intraosseous

Fig. 4 Different view with the 45-degree endoscope of the left infraorbital nerve (ION) from the ipsilateral nostril (A) and contralateral nostril (B) with extended septectomy. In the contralateral nostril approach, the bone surrounding the infraorbital (IO) foramen can be visualized. This specimen has the ION surrounded by thick bone that constitutes the least frequent endoscopic anatomic type.

Fig. 5 Endoscopic endonasal stepwise dissection and transection of the left infraorbital nerve (ION). (A) The ball probe breaks the paper-thin bone of the ION prominence. (B, C) The tip of the ball probe is used to dissect the nerve and artery from the groove and canal; note the surrounding connective tissue that protects these structures. (D, E) The blade transects the ION and artery. Is it easier to cut the nerve distally first so that it is under tension, though the artery needs to be previously coagulated at the origin of the infraorbital (IO) canal. (F) Final view after total removal of the contents of the IO groove and canal. A few millimeters of ION are left exiting through the IO foramen; note the intraosseous branch of the IO artery (arrow).

branches during the dissection (► **Fig. 5**). Coagulation at the posterior wall of the maxillary sinus with angled bipolar electrocautery at the beginning of the dissection is advised.

In this study, the ION was approached and dissected with nasolacrimal duct preservation. Using an ipsilateral approach, it was possible to dissect and resect more than 22 mm of the ION on average when surrounded by thin type bone. The nasolacrimal groove and canal, site of the lacrimal sac and nasolacrimal duct, respectively, are located in front of the anterior border of the middle nasal turbinate. The duct drains to the inferior meatus with a wide base approximately 2 cm behind the nostril.²⁶ If access to the most anterior margin of the nerve is required, sharp transection of the nasolacrimal duct may be necessary. This guarantees wide access to the anterior wall of the maxillary sinus and allows for manipulation with straight instruments, including drills (► **Fig. 6**).

Preservation of the nasolacrimal duct can be achieved by following this structure superiorly from the inferior meatus and identifying the canal with image-guided navigation. Epiphora is a possible complication due to the resection of the nasolacrimal duct during medial maxillectomy, and in 1.9% of cases requires dacryocystorhinostomy.²⁷

Perineural invasion of the ION with skin malignancies, especially squamous cell carcinoma,²⁸ is more frequent than dissemination from sinonasal malignancies, and resection of the tumor, including skin with cutaneous branches of the ION affected, is needed, along with anterior maxillectomy and resection of the ION at the roof of the maxillary sinus. EEA provides greater access and visualization of the proximal nerve if dissection to the Meckel cave is warranted to achieve

maximal resection margin. In the absence of cutaneous involvement, complete excision of a tumor-involved nerve from a sinonasal malignancy can usually be accomplished using an EEA. The most common malignant pathology arising in the sinuses is squamous cell carcinoma, in which the resection of the ION may be necessary if there is tumor invading the IO canal or the nerve itself. Less frequent sinonasal malignancies include tumors with high incidence of perineural spread such as adenoid cystic carcinoma, in which ION resection is often necessary and negative margins in the intraoperative biopsy need to be assessed. The EEA allows access to the ION proximal to the IO foramen but not the cutaneous branches of the ION. Perineural spread can

Fig. 6 View of the right maxillary sinus after sharp cut of the nasolacrimal duct; the infraorbital nerve (ION) can be completely visualized, and straight tools can be used for dissection of its anterior part.

involve all of the branches of the second division of the trigeminal nerve. In cases where the perineural spread involves the second division of the trigeminal nerve proximal to the ION, the pterygopalatine fossa can be safely opened and dissected endoscopically. The maxillary nerve is found as a posterior continuation of the ION in the pterygopalatine fossa entering the middle cranial fossa through the foramen rotundum. The maxillary nerve can be followed and resected endoscopically up to the Gasserian ganglion into the Meckel cave, as previously described.^{29–33}

Conclusion

The ION can be dissected and resected in most cases using an EEA with preservation of the nasolacrimal duct. The contralateral approach provides a better angle for visualization and dissection of the anterior margin of the nerve in the maxillary sinus. The EEA to the ION is ideal in scenarios in which the endoscopic approach can be used for both tumor resection and oncological margins within the ION. The high prevalence of thin bone underlying the ION facilitates the dissection of the nerve.

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