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Endoscopic approach to the trigeminal nerve: An anatomic study

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ABSTRACT

Objective: To describe an endoscopic perspective of the surgical anatomy of the trigeminal nerve.
Methods: Nine adult cadaveric heads were dissected endoscopically.
Results: Opening the pterygopalatine fossa is important because many key anatomical structures (V2, pterygopalatine ganglion, vidian nerve) can be identified and traced to other areas of the trigeminal nerve. From the pterygopalatine ganglion, the maxillary nerve and vidian nerve can be identified, and they can be traced to the gasserian ganglion and internal carotid artery. An anteromedial maxillectomy increases the angle of approach from the contralateral nares due to an increase in diameter of the piriform aperture, and provides excellent access to the mandibular nerve, the petrous carotid, and the cochlea.
Conclusions: Identification of key anatomical structures in the pterygopalatine fossa can be used to identify other areas of the trigeminal nerve, and an anteromedial maxillectomy is necessary to expose the ipsilateral mandibular nerve and contralateral cranial level of the trigeminal nerve.

1. Introduction

Significant advances in cranial base surgery with the application of endoscopic techniques for the management of both benign and malignant diseases have been made in the past decade (Kassam et al., 2005a, 2005b; Snyderman et al., 2008; Taniguchi and Kohmura, 2010), and the use of endoscopy in skull base surgery has become an important alternative to traditional transcranial surgery (de Divitiis et al., 2004; Kassam et al., 2005a, 2005b; Snyderman et al., 2008; Polligkeit et al., 2013). Advances include an improved understanding of endoscopic anatomy, the development of new instrumentation, and the description of new endonasal endoscopic surgical approaches and surgical techniques (Kassam et al., 2005; Cavallo et al., 2007; Fei et al., 2007; de Notaris et al., 2009; Muscatello et al., 2011).

The infratemporal fossa can be involved in both benign and malignant lesions, and although many surgical approaches have been described, most are associated with significant morbidity. Endoscopic endonasal approaches to the middle and posterior cranial fossa, infratemporal fossa, and pterygopalatine fossa have been developed and offer improved surgical exposure with less morbidity than conventional surgical techniques (Alfieri et al., 2003; de Divitiis et al., 2004; Fortes et al., 2008; de Notaris et al., 2009; Taniguchi and Kohmura, 2010; Theodosopoulos et al., 2010). There have been few systematic studies describing the endoscopic endonasal approach to the trigeminal nerve (Chen et al., 2008; Komatsu et al., 2012; Zhang et al., 2012).

The trigeminal nerve is the largest and most complex of the 12 cranial nerves, and is comprised of three divisions which innervate the forehead and eye (ophthalmic nerve, V1), cheek (maxillary nerve, V2), and lower face and jaw (mandibular nerve, V3). Trigeminal neuromas are the second most common intracranial neuromas, and can arise from the Meckel's cave region and extend toward the cerebellopontine angle (Samii et al., 1995; Goel et al., 2003; Pamir et al., 2007). These lesions may expand superiorly to reach the pterygopalatine fossa, and inferiorly to the infratemporal fossa, and in these cases the use of a single surgical corridor may not allow exposure of the entire lesion. Tumours tend to be large because patients frequently present late in the course of the disease after an initial indolent course. Surgery is the primary treatment for trigeminal neuromas; however, surgical management of these

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lesions is especially challenging because of the inherent risks associated with their anatomic location (Konovalov et al., 1996; Guthikonda et al., 2008; Jimbo et al., 2009). The proximity of vital structures such as the internal carotid artery (ICA), brainstem, cavernous sinus, and cranial nerves precludes wide surgical exposure without significant morbidity.

The purpose of this study was to describe an endoscopic perspective of the surgical anatomy of the trigeminal nerve to provide the anatomic basis needed to perform endoscopic endonasal surgery for trigeminal nerve pathology.

2. Materials and methods

This study was performed at the Human Neuroanatomy Laboratory of the Beijing Neurosurgical Institute, and the local institutional research committee approved the project. Nine adult cadaveric heads were dissected endoscopically. In all cases, individuals had provided written permission for the use of their body specimens for research purposes prior to their death. Prior to dissection, the arteries and veins were injected with red and blue latex, respectively, and the specimens were stored in a 75% alcohol solution.

For dissection, we used rod lens endoscopes, 4 mm in diameter and 18 cm in length, with 0° and 30° lenses (Rudolf Medical GmbH + Co. KG Umkirch Germany). During the endoscopic dissection of a specific structure, photographs were taken with a single lens reflex Pentax K7 digital camera (Pentax, Tokyo, Japan) coupled to the endoscope. The cadaveric specimen was placed in a supine position with the head in a neutral position, and adducted 10–15° toward the left shoulder.

3. Results

3.1. Cranial level of trigeminal nerve

The extended endoscopic endonasal approach to the cranial level of the trigeminal nerve is similar to that used for the clivus region (Solares et al., 2005; de Notaris et al., 2009; Abuzayed et al., 2010). The endoscope was introduced from the right nostril and oriented 10° superiorly, and the inferior wall of the sphenoid sinus and vomer were totally resected. After removal of the posterior part of the nasal septum, a wide anterior sphenoidotomy was completed to expose the sphenoidal segment of the clivus (Fig. 1A). After resecting the inferior wall of the sphenoid sinus and vomer, and retracting the overlying mucosa laterally until the vidian nerve, sufficient exposure of the clivus was obtained (Fig. 1B). The lateral limit of the surgical corridor was the vidian nerve (Fig. 1E, F) (Cavallo et al., 2005; Kassam et al., 2005a; de Notaris et al., 2009).

For an extended approach to the clivus, a wider surgical corridor is needed. An ethmoidectomy with removal of the inferior part of the superior turbinate and middle turbinectomy was performed bilaterally. After the mucosa of the rhinopharynx was removed, and the longus capitis and colli muscles were dissected to expose both the sphenoidal and rhinopharyngeal parts of the clivus. The clivus bone was visualized superiorly from the inferior sphenoid sinus wall to the eustachian tube (Fig. 1B). A venous plexus can be seen in front of the clivus and the C1 vertebra (Fig. 1C, D). A rectangular opening in the clival bone was made with a drill and cutting burr. After exposure of the dura, a vertical dural incision was made to expose the anterior brainstem surfaces (Fig. 2A) (de Divitiis et al., 2004; de Notaris et al., 2009; Abuzayed et al., 2010). The boundaries are the abducens nerve entering the dural porus cranially, and the hypoglossal nerve piercing the hypoglossal canal (Fig. 2A, D). By means of a 30-degree optic lens and a lateral inclination of the endoscope, angling the endoscope superiorly, over the ventral surface of the pons and above the abducens nerve. By turning the endoscope superiorly, the trigeminal nerve was explored along its course from the pons toward Meckel's cave (Fig. 2B, C). In three specimens in which bridging veins were found between the pons and petrosum (Fig. 2B, C), lateral angulation of the endoscopy was limited by the contralateral bone of the piriform aperture. An incision was made at the piriform aperture anterior to the inferior turbinate, and the medial and anterior maxillary wall was resected by drilling. A 1-cm anteromedial maxillectomy was done at the region between the inferior nasal conchae and base of nasal cavity horizontally. The exposure angle of the trigeminal nerve was increased (Fig. 2B, C).

3.2. Maxillary nerve

An endonasal ethmoido-pterygo-sphenoidal approach, and transmaxillary endoscopic approach can expose V2 and the semilunar ganglion (Alfieri et al., 2003; Cavallo et al., 2005; Fortes et al., 2008; Kassam et al., 2009; Hofstetter et al., 2010). The anterior ethmoid sinus and posterior ethmoid sinus were opened, and the opening of the maxillary sinus was identified and was expanded forward and backward. The sphenopalatine artery was exposed and protected, and used as a guide to find the sphenopalatine foramen (Fig. 3A). An electric drill was used to remove the ascending branch of the palatine bone and the posterior wall of the maxillary sinus. The external periosteum was opened, and the pterygopalatine fossa region was entered. After the fat in the pterygopalatine fossa was removed, the proximal segment of the sphenopalatine artery and the posterior nasal artery were further exposed (Fig. 3B). The internal maxillary artery (IMA) was located, and the branches of the IMA in the pterygopalatine fossa were exposed. The IMA and its branches were moved downward and outward to expose the pterygopalatine ganglion (PG), V2, vidian nerve, and greater palatine nerve (Fig. 4A, B). V2 exits the skull base through the foramen rotundum ossis sphenoidalis inferolateral to the cavernous sinus, and then enters the pterygopalatine fossa where it gives off several branches. Its main trunk continues anteriorly in the orbital floor, and emerges to the face as the infraorbital nerve to innervate the middle third of the face and upper teeth. After removal of the pterygoid process, V2 was traced and followed into Meckel's cave (Fig. 4D). The greater palatine nerve can be seen travelling downward vertically along with the descending palatine artery, and entering the pterygopalatine canal. The vidian canal was opened near the anterior genu of the carotid artery (Fig. 4C).

3.3. Ophthalmic nerve and the semilunar ganglion

The trigeminal ganglion is contained within the Meckel's cavity posterolateral to the cavernous sinus on either side of the sphenoid bone. We used a transethmoid-pterygoid-sphenoidal endoscopic approach to the cavernous sinus and Meckel's cave. The periosteum of the inferior wall of the cavernous sinus was removed by a hook knife, thus exposing the lateral wall of the cavernous sinus through the intracavernous internal carotid artery (Fig. 5A). The parasellar segment of the ICA overlaps with the middle third of the cavernous sinus, and posterior to it is the inner aspect of the ICA. The oculomotor and trochlear nerves are located inside the C-shaped ICA. The primary blood supply to the distal segment and the semilunar ganglion is from branches of the inferior cavernous sinus artery. The inferior cavernous sinus artery was present in all specimens (Fig. 5D), and occurred as a single trunk on both sides in all nine specimens. All inferior cavernous sinus arteries were located in the lateral aspect of the horizontal segment of the intracavernous ICA. The inferior cavernous sinus