Neuroanatomical study

Review of complications due to foramen ovale puncture

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Abstract

We aim to evaluate the mechanisms responsible for complications during trigeminal rhizotomy via foramen ovale puncture. Ten dry skulls and 10 skull-base specimens were investigated in the present study. In cadaveric skull-base specimens, the anatomical relationships between the foramen ovale, mandibular nerve and Gasserian ganglion and the surrounding neurovascular structures were investigated intradurally. The distance between the foramen ovale and Gasserian ganglion was measured as 6 mm. The abducent nerve, adjacent to the anterior tail of the petrolingual ligament, was observed passing along the lateral wall of the cavernous sinus. Advancement of the catheter more than 10 mm from the foramen ovale is likely to damage the internal carotid artery and the abducent nerve at the medial side of the petrolingual ligament. Thermocoagulation of the lateral wall of the cavernous sinuses may damage the cranial nerves by heat, giving rise to pareses.

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1. Introduction

Complications may occur after glycerol rhizotomy and electrocoagulation via foramen ovale (FO) puncture, despite both techniques being successful for the alleviation of trigeminal neuralgia (TN). Carotico cavernous fistula due to internal carotid artery (ICA) rupture, temporary or persistent pareses of the cranial nerves, cerebrospinal fluid (CSF) fistula and intracranial haemorrhages are well-known complications of trigeminal rhizotomy.1–6 The aim of the present study is to define the mechanisms of complications of transovale procedures using dry skull measurements and cadaver dissections of the region.

2. Methods

Ten dry skulls and 10 skull bases with brains removed were used in the present study. The diameter of the FO and distances from the FO to the petrous apex, posterior clinoid process, foramen spinosum, foramen Vesalius (FV) and lingula of the sphenoid bone were measured. Ten adult fresh cadaveric heads were used for microsurgical dissection. The skull vault and brain were removed and the heads were embalmed in 10% formalin solution.

The dura mater of the middle fossa was stripped off the bone in a lateral to medial direction and anteriorly to the superior orbital fissure (SOF). The periostal bridge, formed by the union of the periostal dura with the periorbita just over the SOF, was separated by sharp dissection, thereby the superficial layer of the dura propria covering the lateral wall of the cavernous sinus was dissected posteriorly. The deeper layer of the dura propria overlying the cranial nerves located within the lateral wall of the cavernous sinus, Gasserian ganglion (GG) and the mandibular branch of the trigeminal nerve were exposed. The dura mater on the petrous bone was lifted up, protecting the greater superficial petrosal nerve (GSPN) in its sulcus. After cutting off the branches of the trigeminal nerve, the base of the middle fossa, the FO with its surrounds, the petrous apex and the area posterior to cavernous sinuses were all exposed.
3. Results

3.1. Skull base measurements

The maximum diameter of the FO ranged between 6.9 and 7.2 mm. The average distance from the FO to the surrounding bony landmarks was 26.1 mm (range 24–29 mm) from the posterior clinoid process, 14 mm (range 12–16 mm) from the petrous apex, 9 mm (range 8–10 mm) from the foramen rotundum, 3 mm (range 2.9–3.1 mm) from the foramen spinosum and 4.9 mm (range 4–5.1 mm) from the lingula of the sphenoid bone (Fig. 1). The FV was demonstrated in all skulls (Fig. 2). The FV, with a mean diameter of 1 mm (range 0.8–1.2 mm), was located between the FO and foramen rotundum and 4 mm (range 3–5 mm) anteromedial to the FO. In all 10 dry skulls, a gap was found between the temporal fossa and the dome of the lacerum segment of the petrous canal where the ICA passes through.

3.2. Dural membranous structure

The dura mater is composed of two layers, the dura propria inside (brain side) and the periosial layer outside (bone side). The dura propria is mesenchymal tissue and, on the brain side, is separated into a smooth superficial layer that is adjacent to the arachnoid membrane and semitransmembraneous-like deeper layers, corresponding to mesenchymal tissue.8–10 The deeper layer envelops the cranial nerves in the form of a reticular membrane.10,11 The periosial dura propagating medially overlies the body of the sphenoid bone, thereby forming the sellar floor.11 The outer periosial layer encircles the FO and foramen rotundum, including the second and the third divisions of the trigeminal nerve (V2 and V3), and unites with nerve sheaths in the extracranial compartment (epineurium; Fig. 3A).

3.3. Trigeminal nerve

The subarachnoid space in Meckel’s cave ends at the level of the GG. The average distance between the FO and the dural entry point of the fifth nerve was 12.1 mm (range 11.8–13 mm), whereas the mean distance from the FO to the GG was 6 mm (range 5.8–6.3 mm).

3.4. Foramen ovale in relation to the petrolingual ligament

The petrolingual ligament (PLL) lies on the medial side of the FO and runs between the lingula of the sphenoid bone anteriorly and the petrous apex posteriorly (Fig. 4).10,12 The mean distance between the medial rim of the FO and the most concave side of the PLL was 10.1 mm (range 9.8–10.4 mm).

3.5. Foramen ovale in relation to the greater superficial petrosal nerve

After exiting the facial hiatus almost 8.1 mm (range 7–9 mm) lateral to the petrous ridge, the GSPN proceeds forward approximately 18.9 mm (range 18–20 mm) parallel to the ridge in order to reach under the lingula, which is located 3.2 mm (range 3–4 mm) posterosmedial to the FO.

3.6. Foramen ovale in relation to the arteries

The mean distance between the FO and the ICA was 10.3 mm (range 8–12 mm) at the level of the PLL and 20 mm (range 18–22 mm) at the level of the posterior clinoid process. Hence, the shortest distance between the FO and the ICA was 10.3 mm, and the greatest distance was 20 mm. Branches from the inferolateral trunk travel superiorly and inferiorly. Superiorly directed branches feed the
oculomotor, trochlear and ophthalmic branches of the trigeminal nerve, whereas the inferiorly directed branches feed the abducens nerve, maxillary and mandibular branches of the trigeminal nerve and the periosteodural elements in this region. Branches from the inferolateral trunk anastomose with the distal part of the accessory meningeal artery, which passes through the FO (Fig. 4). The tentorial branch of the meningohypophyseal artery of the ICA (Bernasconi-Cassinari artery) proceeds to the posterolateral part of the cavernous sinus and gives off tiny branches to the dura of the trigeminal artery. The branch from the middle meningeal artery extending into the sphenoid ridge, anastomoses with the lateral branch of the ophthalmic artery within the SOF and then extends posteriorly within the lateral wall of the cavernous sinus as a tiny artery, called the recurrent meningeal artery, beneath the trochlear artery. The dura of Meckel’s cave is fed by the tentorial artery, a branch from the middle meningeal artery rerouting medially, and by a distal segment of the recurrent meningeal artery (Fig. 4).

The middle meningeal artery is located posterolateral to the FO, enters the cranium via the foramen spinosum and extends anterolaterally after passing through the sphenoid ridge. The distance to the FO was 3 mm. Tiny branches take off from the middle meningeal artery to nourish the GG sleeve.

3.7. Foramen ovale in relation to venous structures

The cavernous sinus is located medial to the FO, whereas the superior petrosal sinus is located posteriorly. A venous network connects the cavernous sinus, which encircles the FO, spinosum, Vesalius and lacerum with the deep component of the pterygoid plexus (Fig. 3B). The superior petrosal sinus extends over the dural entry point of the trigeminal nerve.

3.8. Foramen ovale in relation to the nerves within the cavernous sinus

The third nerve being superior, anterior and medial to the FO penetrates the dura at the roof of the cavernous

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sinus. The distance between this structure and the FO was 20.8 mm (range 18–23 mm). The distance between the FO and the trochlear nerve in the FO-posterior clinoid process plane was 18 mm (range 16–20 mm). The sixth nerve passes beneath the petrosphenoidal ligament and traverses the petrous apex at a point medial to the posterior tail of the PLL, where it crosses over the lateral wall of the posterior knee of the ICA. The abducens nerve pierced the dura mater with its couple in two of 20 specimens, one crossing over the petrosphenoidal ligament in one specimen. The abducens nerve anastomoses with the post-ganglionic perianterial sympathetic plexus and with some fine bundles of the trigeminal nerve on the lateral wall of the ICA.

4. Discussion

Trigeminal neuralgia (TN) is the most frequently occurring of the craniofacial neuralgias. For patients in whom medical treatment fails to control pain, microvascular decompression, glycerol rhizolysis, radiofrequency thermocoagulation and percutaneous trigeminal microdecompression procedures have been devised in an attempt to alleviate idiopathic TN. Various complications, including death, may follow FO puncture. CSF discharge observed in FO puncture is evidence that the catheter has been inserted into Meckel’s cave. The flow of CSF is checked by advancing the puncture needle less than 5 mm after visualization under the fluoroscope and then withdrawal of the styllet of the catheter. The region between the FO and GG is filled not only with mandibular roots, but also with mesenchymal tissue. Therefore, leakage of CSF is prevented by catheter withdrawal as the hole is obstructed. However, CSF leaks have been reported in 0.13% of cases. It has also been reported that the posterior fossa dura, together with the arachnoid membrane, may end at the level of the GG or extend to the FO all the way through to the mandibular nerve. This type of anatomical variation may cause CSF fistula.

4.1. Neural complications

Blindness due to optic nerve injury at the time of percutaneous rhizotomy has been reported. Inadvertent introduction of the rhizotomy needle into the inferior orbital fissure instead of the FO has been documented at autopsy. Oculomotor paresis is seldom encountered after FO puncture. The oculomotor nerve pierces the dural porus within the oculomotor trigone at the roof of the cavernous sinus and then enters the SOF after travelling within the lateral wall of the sinus for a distance. It does not seem possible for the catheter to reach the oculomotor nerve or its branches via the FO. A puncture direction perpendicular to the clival line is needed for rhizotomy and directing the catheter toward the anterior clinoid process would be required in order to reach the third nerve. However, cases in which the needle has accidentally been introduced into the inferior orbital fissure or the SOF, thereby injuring the third nerve, have been reported in the literature.

The trochlear nerve extends right over the ophthalmic nerve within the lateral wall of the cavernous sinus. This is why procedures involving the ophthalmic branch may also cause fourth nerve injury. Another mechanism for trochlear nerve palsy is thermocoagulation injury of the feeding recurrent meningeal artery, which travels between the fourth nerve and the ophthalmic branch of the trigeminal nerve. Trochlear palsy developing immediately after electrocoagulation seems to support this theory. Deeper and more medial penetrations may also contribute to the development of fourth nerve palsy.

Injury to the nasociliary nerve, which supplies the afferents for the corneal reflex, results in the abolition of the corneal reflex and the risk of corneal keratitis. The incidence of weakness has been reported as 24% with the use of straight-tipped electrodes, whereas it is only 7% using curved-tipped electrodes.

The incidence of abducens palsy during rhizotomy has been reported as 0.75%. The propensity of abducens palsy to occur in elderly patients may reflect an increased vulnerability of the abducens nerve to injury with aging. This may be because of less viable intraneural microvessels, diminished production of trophic factors by Schwann cells and impairment of the ability of the Schwann cells to maintain adequate myelin sheaths. Mechanical injury, as well as vascular impairment, of the nerve plays a role in the development of sixth nerve palsy. Anastomoses between the fifth and sixth nerves facilitate sixth nerve palsy at the time of the rhizotomy procedure. Additionally, the abducens nerve travels adjacent to the PLL, which makes it the most involved cranial nerve. The abducens nerve is duplicated in 18% of cases. As was found for one of the cases examined in the present study, this type of variation predisposes to partial impairment of abducens nerve function owing to injury of one of the two nerves.

Injuries to cranial nerves 7, 8 and 12 have also been reported as a result of improper direction of the needle. In a series of 1433 patients, Harris noted gustatory abolition involving half the tongue and palate in 167 patients. He believed this may have developed as a result of injury to the GSPN and/or the geniculate ganglion.

4.2. Vascular complications

Carotidocavernous fistula is rare, but it is the most catastrophic complication and its incidence depends on the...
surgeon’s experience. In our dissections, the site of the fistula, which was found to be directly related to the FO and ICA, was the medial part of the PLL. In particular, a tortuous ICA has been reported to predispose to the development of this complication. It was reported that thermal injury during radiofrequency lesioning may extend to involve vascular structures. At the time of FO puncture, subarachnoid and subdural haemorrhages may develop in the deep temporal lobe. The haemorrhages may develop as a result of direct injury of the intracranial vessels by the needle used. The FO, trigeminal ganglion and trigeminal nerve branches in the cavernous sinus are rich in surrounding vascular structures. The needle used is most likely to cause direct damage, particularly to the anastomosing venous structures between the cavernous sinus and the pterygoid plexus, which pass through the FO and FV.

Hypertension and prolonged bleeding time have been reported during percutaneous rhizotomy. It is believed that these responses are probably due to a direct pressor reflex and not to a secondary rise in the pressure evoked by stimulation of pain fibres. Another complication that may follow percutaneous rhizotomy is external carotid artery fistula. Revuelta et al. explained this rare complication as a result of puncture of the middle meningeal artery near its take-off from the pterygopalatine artery caused by a postero-lateral direction of the needle emerging from the FO.

References
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