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ANATOMIC BASES OF MEDICAL, RADIOLOGICAL AND SURGICAL TECHNIQUES

Endoscopic transsphenoidal optic nerve decompression: an anatomical study

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Abstract
Purpose The endoscopic trans-nasal, transsphenoidal approach is considered by many a valid option to reach the sellar region and, in selected case, to decompress the optic nerve. However, few data are available from the literature about the real effectiveness of the procedure and the extent of nerve decompression needed to obtain a clinical result. The aim of this anatomical study was to describe the most important landmarks of the endoscopic transsphenoidal approach to the optic nerve.
Methods Six silicone-injected cadaver heads were dissected via the endoscopic trans-nasal approach, performing a bilateral optic nerve decompression. The lateral opto-carotid recess (OCR) and optic canal were identified in each case. Moreover, the relationship between the ophthalmic artery at its origin and the optic nerve was examined.
Results 12 decompressions of the optic nerve were performed, obtaining the following measurements: intercarotid distance 12 mm ± 1.5, median length of OCR 5 mm ± 1, average length of optic nerve decompression 15 mm ± 2. The ophthalmic artery was observed emerging from the internal carotid artery (ICA) medially in six cases, ventrally in four cases and laterally in two cases.
Conclusion A wide optic nerve decompression may be obtained with transsphenoidal approach. However, the risk of ophthalmic artery injury seems to be more relevant than with supratentorial approaches, due to the intimate relationship between artery and nerve on its inferior surface. Knowledge of anatomical landmarks, such as lateral OCR and the position of the ophthalmic artery, is useful to prevent this injury.

Keywords Endoscope · Transsphenoidal · Optic nerve · Skull base surgery

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Introduction

The sellar region is a complex part of the skull base because of its multiple anatomical structures, among all the optic nerves. For this reason, the region could be defined both from an anatomical and a functional point of view [20, 21].

Many surgical approaches have been described to reach this region [7, 10, 16, 22, 23, 25].

One classification distinguishes between intracranial and transsphenoidal approaches, the last ones being considered less invasive than supratentorial ones [8].

More recently, the transsphenoidal endoscopic technique has been considered by some authors a new and more valid alternative than the "classical" microsurgical one [3, 8, 12]. This surgical approach has been chosen, in selected cases, to decompress the optic nerve [5, 13, 14]. Cranio-facial trauma, medical refractory pseudotumor and thyrotoxic orbitopathy are examples of such cases [14, 18, 19, 24], even if the usefulness of decompressing the II cranial nerve in its intracanalicular part is still debated [19].

In this paper, we have performed an anatomical description of the course of the optic nerve during a transsphenoidal approach performed to decompress the nerve itself.

Main objectives of the study are to describe the most significant structures and landmarks encountered during this procedure, the aspects of anatomy that are relevant to surgery and the extension of nerve decompression that may be obtained with this approach.

Measurements of dimensions and reciprocal relationships of the optic nerve with carotid and ophthalmic artery were reported, underlying the importance of their anatomical variability. Moreover, we compared the transsphenoidal approach with the intracranial one discussing the pro and contra of the two options.

Materials and methods

Six human cadaveric fresh heads were used. On these heads, only the arterial system was injected with red coloured silicone rubber (Dow Corning Corp., Midland, MI, USA). All dissections were performed at the Institute of Anatomy of the University of Vienna.

Rigid endoscopes that were 4 mm in diameter, 18 cm in length, with 0° and 45° lenses (Karl Stortz GmbH & Co, Tuttlingen, Germany) were used. The endoscope was connected to a light source via a fiberoptic cable and to a camera. The video camera was connected to a 21-inches monitor. To guarantee a suitable file of anatomical images, a digital video recorder system (DVCam) was used.

A standard endoscopic endonasal approach to the sphenoid sinus was performed in each case, using a 0° lens endoscope in the initial phase. Cadavers with great or well pneumatized sphenoid sinus make this approach easier. Bilateral optic nerve decompression was performed in each specimen. The endoscope was initially introduced through the right nostril, close to the floor of the nasal cavity, leading to the identification of the nasal septum, the inferior and the middle turbinate. With a gentle lateral dislocation of the head of the middle turbinate, an adequate surgical corridor toward the posterior nasal cavity was obtained. Advancing the endoscope, the choana, that represents the inferior landmark of the approach, was visualized. As the choana was reached, the endoscope was angled rostrally, along the roof of the choana and the sphenoethmoid recess.

The sphenoid ostium was usually identified approximately 1.5 cm above the roof of the choana. Sometimes the ostium was covered by superior turbinate and its identification was difficult: in these cases, it was necessary to lateralize the superior turbinate or to remove it, in order to gain access to the sphenoidal sinus. After entering the sphenoid sinus through the ostium, the anterior wall of the sinus was removed. The sphenoid rostrum was separated from the nasal septum and a standard anterior sphenoidotomy was performed. The extent of the anterior sphenoidotomy was comparable to that usually performed during pituitary surgery. After the anterior sphenoidotomy was completed, septa inside the sphenoid sinus were eventually removed with Kerrison and rongeurs. After accurate removal of the sphenoid septa, full visualization of posterior and lateral walls of the sinus was obtained.

The bony anatomical landmarks of the sphenoid sinus were then identified: the optic nerve protuberances, the carotid protuberance, and the lateral opto-carotid recess (OCR), at about the 10-o'clock and the 2-o'clock points laterally to the sellar floor.

The optic nerve protuberance is the bulge made by the optic canal on the sinus cavity side of the lateral sphenoid sinus wall.

The carotid protuberance belongs to the lateral wall of the body of the sphenoid bone. The anterior bend (C3 segment) of the internal carotid artery (ICA) courses along to this bone and form the osseous convolutions on the inner surface of the sphenoid sinus.

The lateral opto-carotid recess represents the pneumatisation of the optic strut of the anterior clinoid process. It is located between the osseous prominences of the internal carotid artery (ICA) below and of the optic nerve above.

Optic nerve decompression was then performed from the chiasm to the distal wall of the orbit (the decompression was stopped with the identification of the lamina papiracea and the Zinn anulus). The decompression was obtained with the use of the Hardy dissector and with a high speed micro drill when the bone was too thick.

For every specimen it was possible to obtain a wide bilateral decompression of the optic nerve from the region of the chiasm to the lateral wall of the orbit.

The measurements obtained were:

- the distance between carotid arteries and optic nerves protuberances,
- the extent of optic nerve decompression.

The second part of the study was focused on the anatomical relationship between the ophthalmic artery at its origin, the carotid artery and the optic nerve.

Results

Decompression of the optic nerve was achieved in all the 6 human cadaveric fresh heads bilaterally.

The surgical approach was the "pure" endoscopic transnasal approach described to reach the pituitary gland and sellar region. As documented, the key anatomical landmarks were recognized and highlighted during every step of the approach.

In the first phase of the procedure (nasal one) we focused on the choana/aditus, the rhinofaryngeal region, the middle turbinate and the sphenoidal ostium (1.5 cm above the choana) (Fig. 1a).

In the second phase (sphenoidal one) the attention was moved over the sphenoidal septum, the carotid artery protuberance (CP), the optic nerve protuberance (OP) and the lateral OCR.

The following measurements were obtained: intercarotid distance (the median distance between the two CPs) 12 mm ± 1.5, median length of lateral OCR (which correspond to the distance between the parasellar carotid artery and the optic nerve) 5 mm ± 1 (Fig. 1b, c).

In the third phase (optic nerve one), the bony wall, surrounding the nerve, was removed (Fig. 2a).

The average length of optic nerve after decompression was 15 mm ± 2 (Fig. 2b). This measurement was greater than the length of optic canal classically reported in previous anatomical studies.

The explanation of this difference was the extension of the decompression, which was conducted from the orbit to the chiasm, so that the part of nerve exposed was not only the intracanalicular one but also the intracranial and orbit ones. The unfolding of "lamina papiracea" and the Zinn's annulus confirmed the correct exposure of the orbit (Fig. 2c, d).

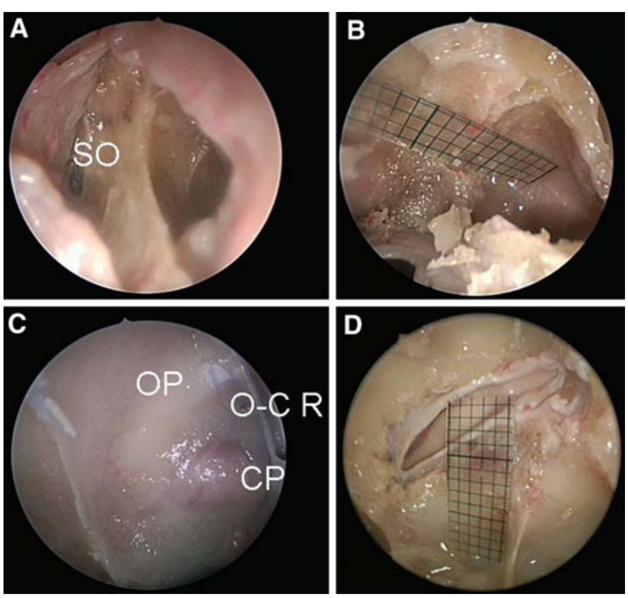

Fig. 1 **a** Endonasal step, visualization of sphenoid ostium (SO). **b** Sphenoid step: removal of septum, carotid and optic identification, measurement of intercarotid distance. **c** Visualisation of the optic nerve protuberance (OP), the carotid artery protuberance (CP) and the optic-carotid recess (OCR). **d** Measurement of distance between the carotid artery and the optic nerve

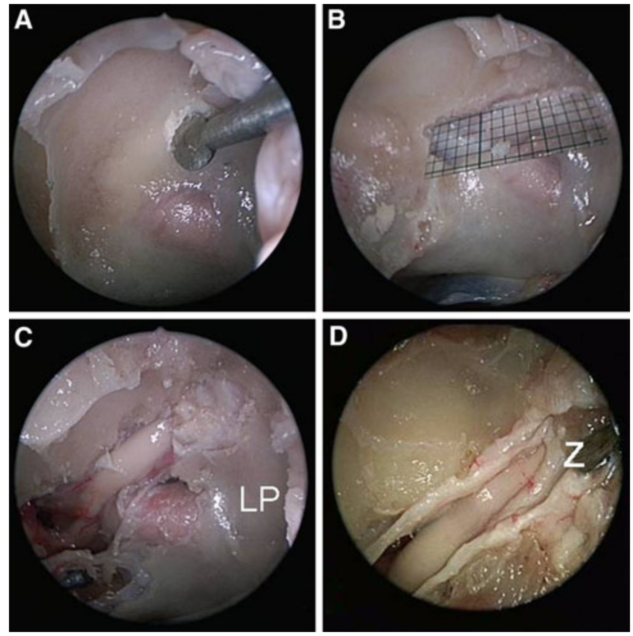

Fig. 2 **a** Optic nerve decompression. **b** Measurement of the optic nerve decompression. **c**, **d** Optic nerve decompression with visualisation of lamina papiracea (LP) and of Zinn's annulus (Z)

The exposition of the ophthalmic artery, in order to demonstrate its relationship with the optic nerve, was another aim of the study (Fig. 3a). In the specimens, the artery emerged from the internal carotid artery inferomedial to the nerve in 6/12 decompressions (50%), inferior in 4/12 (30%) and inferolateral in 2/12 (20%). Ophthalmic artery's entrance in the optic canal followed the same topography with the same percentages. In the same specimen, no difference was remarked between the two sides.

In order to verify the measurements, all the bony parts surrounding the arteries and nerves were removed. In this way the communicating artery-anterior cerebral arteries complex, the ophthalmic artery, the pituitary gland and its stalk were exposed (Fig. 3b).

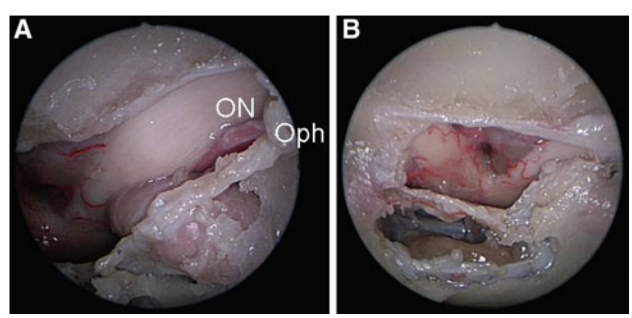

Fig. 3 **a** Visualization of the ophthalmic artery, and its relationship with the optic nerve. **b** Anatomical relationship between optic chiasm and pituitary gland

Discussion

The great number of vascular and nervous structures inside the sellar region makes this portion of the skull base one of the most complex of the human body. Because of this complexity it still represents a real challenge for neurosurgeons.

Many different approaches, both transcranial and transphenoidal, have been described to reach this region. Among the transphenoidal approaches the endoscopic one has gained popularity in the last years. Its low invasiveness and the possibility of an excellent visualisation are the main reasons of this popularity. This approach has been proposed for treating lesions of the sellar and parasellar region like pituitary adenomas, meningiomas and craniopharingiomas. Crucial in this approach is the intraoperative use of neuroradiological exams, such as fluoroscopy and/or neuronavigation with CT/MR scan, to identify anatomical landmarks.

Among surgical indications for this approach, decompression of the optic nerve represents a particular one. According to classical anatomical descriptions [20], the second cranial nerve course could be divided into 4 parts, starting from the optic papilla. The first one is the intraocular one and it is made of the amyelinic fibers arising form the optic papilla. Leaving the ocular bulb, these fibers acquire myelin and the three meningeal sheaths. The second one is the orbital portion: its length is about 30 mm. The third one is the intracanalicular one (8 mm) from the orbit to the optic foramen. The fourth part is the intracranial part. It ends at the chiasm and it is about 10 mm long. The properly defined optic canal is represented by the bony part of the optic course.

Optic nerve decompression is a surgical technique invocated in selected pathological conditions such as pseudotumor cerebri and craniofacial trauma [18, 19]. The aim of this procedure was to remove the bony wall of the optic canal in order to relieve the oedematous nerve. This surgical strategy is a well known therapeutical concept and it is applied in different pathological conditions in neurosurgery. However, decompression of the optic nerve remains a procedure not completely accepted yet. The difficulty to evaluate the real effectiveness of this procedure compared to its elevated risks are among the reasons of the controversy. Moreover, surgical series are always inadequate in numbers and incomplete in clinical, radiological and follow up evaluation. The first and classical approach described in the literature to decompress the optic nerve is the transcranial one (pterional with both an extradural and intradural recognition and decompression of the nerve). Over last years the endoscopic transsphenoidal approach for sellar and parasellar lesions gained popularity [2, 4, 9].

In the present study we have illustrated decompression of the optic nerve by an endoscopic transsphenoidal approach which in the first part (nasal one) is not different from the "pure" endoscopic approach to the pituitary gland.

Landmarks which identify the most relevant anatomical structures were highlighted in order to avoid "dangerous" situations and to define the optic course. We were able to identify the OP and the OCR in all specimens. Like in previous studies [17], we found the lateral OCR to be the most reliable landmark that allow to identify the optic nerve and its direction, the internal carotid and ophtalmic artery.

Our measurements (intercarotid distance, length of lateral OCR, and length of optic nerve) showed that significant decompression of the optic nerve starting from the optic recess to the medial part of the orbit and to the chiasm. The average length of the optic nerve decompressed measured 15 mm $\pm$ 2. This measure represents the exposure of the nerve both in the intracanalicular part and in the intracranial one.

Knowledge of these landmarks and measurements are essential in order to avoid fatal mistakes and to obtain a proper space of work. Use of a microdoppler probe to discover the ICA, however, must be considered when the intercarotid distance is small ("kissing" of carotid arteries), or when there is uncertainty about the localization of the carotid protuberances, as in reinterventions.

We also demonstrated a great variability of the ophthalmic artery at its origin, with different sectors of entrance in the optic canal by the artery. In the majority of specimens (50%), the artery was found to be inferomedial to the nerve at the intracranial opening of the optic canal, whereas it is inferior to the nerve in the optic canal in the majority of cases. Based on this observation, it is safer to open the optic sheath in its medial part while decompressing the nerve in the optic canal. These anatomical findings are very similar to those reported in previous studies [11, 15, 17].

In 30% of our specimens, the artery originate from the internal carotid artery directly inferior to the nerve at the intracranial opening of the canal. This finding has also been reported in a previous study by Li et al. in 19% of cases [17]. In this study, the authors were also able to demonstrate a bony canal (the ophthalmic canal), located within the inferior optic canal wall. From a surgical point of view, one should keep in mind that the ophthalmic artery can be injured when working near the intracranial opening of the canal, when its inferior wall is drilled. Knowledge of position and anatomical relationships of the artery with the optic nerve are crucial during the exposed surgical procedure. The anatomical variability of these structures underlines the importance of detailed neuroradiological studies (e.g. a CT with angio-CT) before procedure.

In our opinion, main advantages of this approach are the extension of the decompression obtained and its relative safety. Another important reason in favour of the transnasal approach is the surgical anatomy of the pterional approach. This approach allows for direct exposure of the anterior clinoid process, that forms the lateral margin of the optic canal, and of the dural folds that are attached to this process. The falciform ligament is a dural fold that extends from the anterior clinoid process across the top of the optic nerve, just proximal to the optic canal, to the tuberculum sellae. This fold continues posteriorly to form the anterior petro-clinoid fold, which is the free edge of the tentorium.

The falciform ligament seems to be in the ideal position to guillotine the optic nerve [20, 21]. The necessity to cut the ligament during the cranial strategy due to its position is avoided in the proposed endoscopic technique. Moreover, the anterior clinoid process is spared using this technique, and extension of decompression obtained in our specimens (involving at least two different sectors of the anatomical course) resulted to be wider than that achievable by transcranial approach [1, 6].

Risk of cerebrospinal fluid (CSF) leak may represent a problem after optic nerve decompression especially if completed by dural sheath fenestration. This risk is related to the anatomy of the prechiasmatic cistern, which sometimes is well-developped and extends inferiorly towards the diaphragm, and laterally to include the intracranial part of the optic nerves. Opening of this cistern during nerve decompression may lead to postoperative leaks. Different strategies have been described in the literature to solve CSF leaks [2, 4].

Low invasiveness and wider exploration of the operative field are the cardinal points of strength of the endoscopic technique.

Conclusion

Transsphenoidal approach may be considered an alternative way to perform optic nerve decompression.

Although the data reported here should be considered carefully, this study being an anatomical and not surgical, we conclude that decompression of the II cranial nerve obtained during trassphenoidal approach is satisfactory.

Main advantages of this technique are the low invasiveness, the avoidance of cutting the falciform ligament and the possibility of a wide exploration of the operative field.

Exact knowledge of the variability of the origin of the ophthalmic artery and its anatomical relationship with internal carotid artery and optic nerve are crucial for this approach.

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Conflict of interest None.

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