Transpalpebral transorbital endoscopic lateral approach to the middle cranial fossa: anatomical study in cadaver

Juan R. Gras-Cabrerizo[1,2], María Martel-Martin[2,3], Maria Casasayas-Plass[1,2], Juan C. Villatoro-Sologaistoa[2,4], Ainhoa García-Lliberós[5], Humbert Massegur-Solench[1], Francisco Reina[6], Fernando Muñoz-Hernández[7]

[1] Department of Otolaryngology/Head and Neck Surgery, Hospital de la Santa Creu i Sant Pau, Universitat Autònoma de Barcelona, Spain

[2] Department of Otolaryngology/Head and Neck Surgery, Corachán Clinic, Spain

[3] Department of Otolaryngology/Head and Neck Surgery, Hospital del Mar, Universitat Autònoma de Barcelona, Spain

[4] Department of Otolaryngology/Head and Neck Surgery Hospital General de Catalunya, Universitat Internacional de Catalunya, Spain

[5] Department of Otolaryngology/Head and Neck Surgery Hospital Universitario de Valencia, Spain

[6] Department of Ciencias Médicas (Grupo de Investigación en Anatomía Clínica, Embriología y Neurociencia NEOMA) Universitat de Girona, Spain

[7] Department of Neurosurgery, Hospital de la Santa Creu i Sant Pau, Universitat Autònoma de Barcelona and Corachán Clinic, Spain

SUMMARY

Transorbital expanded endoscopic approaches allow different areas of the skull base to be approached. The aim of our study is to analyse the main anatomical bone and neurovascular structures of the middle cranial fossa by means of a transpalpebral transorbital lateral endoscopic approach (TTLEA). An anatomical study was performed on 12 orbital cavities corresponding to 6 cadaver heads. All specimens were previously injected with colored latex through both carotid systems.

The mean distance from the orbital rim to the zygomatic-facial foramen and to the zygomatic-temporal foramen was 11 mm and 16 mm respectively. In all cases the meningo-orbital foramen was found at a mean distance from the orbital rim of 34 mm. The superior orbital fissure (SOF) was located posterior to the meningo-orbital foramen at 39 mm. The foramen rotundum and foramen ovale were located separated from each other by 10 mm on average. Anterior to the foramen ovale a bony prominence was observed in all cases. In 11 cases (92%) the entrance of the accessory meningeal artery into the foramen ovale was evident and in one case an accessory foramen was observed. The middle meningeal artery was located in all dissections within the foramen spinosum. The TTLEA offers a wide and direct exposure of the middle cranial fossa. It should be considered as an alternative to transcranial approaches in certain lesions invading the lateral region of the middle cranial fossa, the lateral wall of the cavernous sinus or the infratemporal fossa.

Corresponding author:
Juan Ramón Gras-Cabrerizo. C/ Mas Casanovas 90, 08041 Barcelona, Spain. Phone: 34-93-5565679. E-mail: jgras@.santpau.cat

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INTRODUCTION

In recent years, endonasal endoscopic approaches have exponentially expanded their indications, reaching territories usually treated by other specialties. Expanded transnasal approaches have made it possible to approach different areas of both the skull base and the orbital cavity. The main limitation they present is being able to reach certain lateral areas without having to cross vital neurovascular structures. In order to access these anatomical territories with the minimum possible morbidity, the alternative is to use the orbital cavity as a corridor. Historically, in the late 19th century, the first surgical approaches to the orbit were used in the treatment of thyroid orbitopathy (Alper, 1995), and in the early 20th century, lateral (frontotemporal) approaches were described to treat orbital tumours (Dandy, 1941). With technological advances and improvements in radiological studies, these lateral approaches evolved, with increasingly smaller craniotomies being performed. In 1971 Donald Wilson first used the surgical term keyhole or microcraniotomy (Wilson, 1971). The use of the endoscope as a support instrument had a decisive influence on the development of this concept, with the supraorbital keyhole becoming particularly popular in the 1990s (Ramos-Zúñiga, 1999; Eroglu et al., 2019). Moe et al. (2010) and Rivkin et al. (2013) described a series of transorbital endoscopic approaches preserving the orbital rim to treat different pathologies, which he called TONES (transorbital neuroendoscopic surgery). In recent years, several anatomical studies have been published that have made it possible to systematise these endoscopically assisted approaches (Koppe et al., 2013; Dallan et al., 2017, 2018; Di Somma et al., 2018).

The aim of our study is to analyse the main anatomical bone and neurovascular structures of the middle cranial fossa (MCF) using an endoscopic lateral transorbital transpalpebral endoscopic approach.

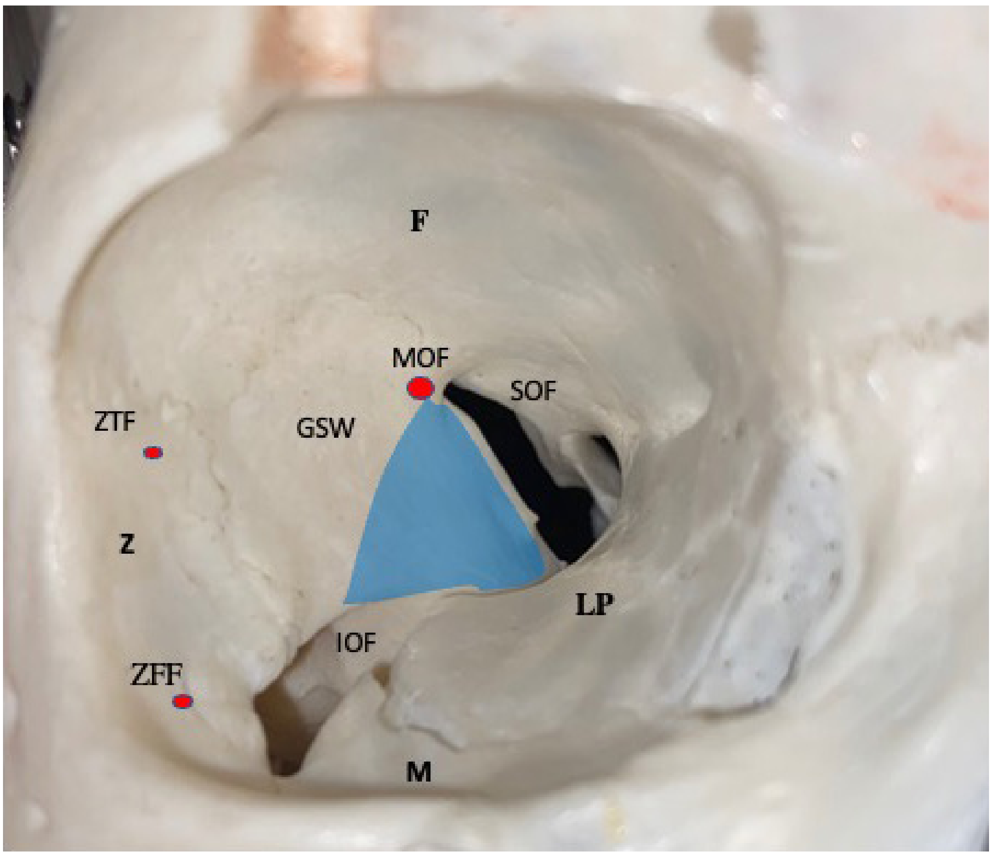

Fig. 1.- Right orbital cavity. In blue access area middle cranial fossa. Z: zygomatic bone; GSW: greater sphenoid wing; M: maxillary bone; SOF: superior orbital fissure; IOF: inferior orbital fissure; ZFF: zygomatic facial foramen; ZTF: zygomatic temporal foramen; MOF: meningo-orbital foramen; LP: lamina papyracea; F: frontal bone.

MATERIALS AND METHODS

An anatomical study was carried out on 12 orbital cavities corresponding to 6 cadaver heads prepared and preserved the modified Larsen's solution. All specimens were obtained from the body donation programme of the University of Girona, which is regulated according to the ethical and legal laws of our country. All specimens were previously injected with colored latex through both carotid systems. A graduated malleable hysterometer and a rigid precision ruler were used for the different measurements.

Surgical technique. An incision was made in the superior palpebral fold approximately 10 mm from the palpebral margin, dissecting from superficial to deep the skin and the orbicularis oculi muscle in its pretarsal, preseptal and orbital portions. Superficial to the orbicularis oculi muscle, the lateral orbital rim was approached and a deep subperiosteal dissection was performed, displacing the orbital contents medially, thus locating the superior orbital fissure (SOF) and the inferior orbital fissure (IOF). During this dissection of the lateral wall, the zygomatic-facial foramen, the zygomatic-temporal foramen superiorly and the meningo-orbital foramen in depth were identified. The distance of these orifices from the orbital margin was calculated from the frontozygomatic suture (Fig. 1). The orbital lateral wall was then drilled until the temporalis muscle fascia was exposed, and the greater wing of the sphenoid was drilled between the SOF and the IOF until the dura mater of the temporal lobe was exposed (Fig. 2). With a blunt instrument, the floor of the MCF was dissected, displacing the temporal lobe superiorly, identifying from medial to lateral, the foramen rotundum with the maxillary nerve (V2), the foramen ovale with the mandibular nerve (V3) and the accessory meningeal artery (AMA) and finally the foramen spinosum with the middle meningeal artery (MMA) (Figs. 3 and 4).

The distance between the foramen ovale and the foramen rotundum was measured from the posterior margin of the foramen ovale to the anterior margin of the foramen rotundum. Finally, along the lateral margin of the SOF we identified the

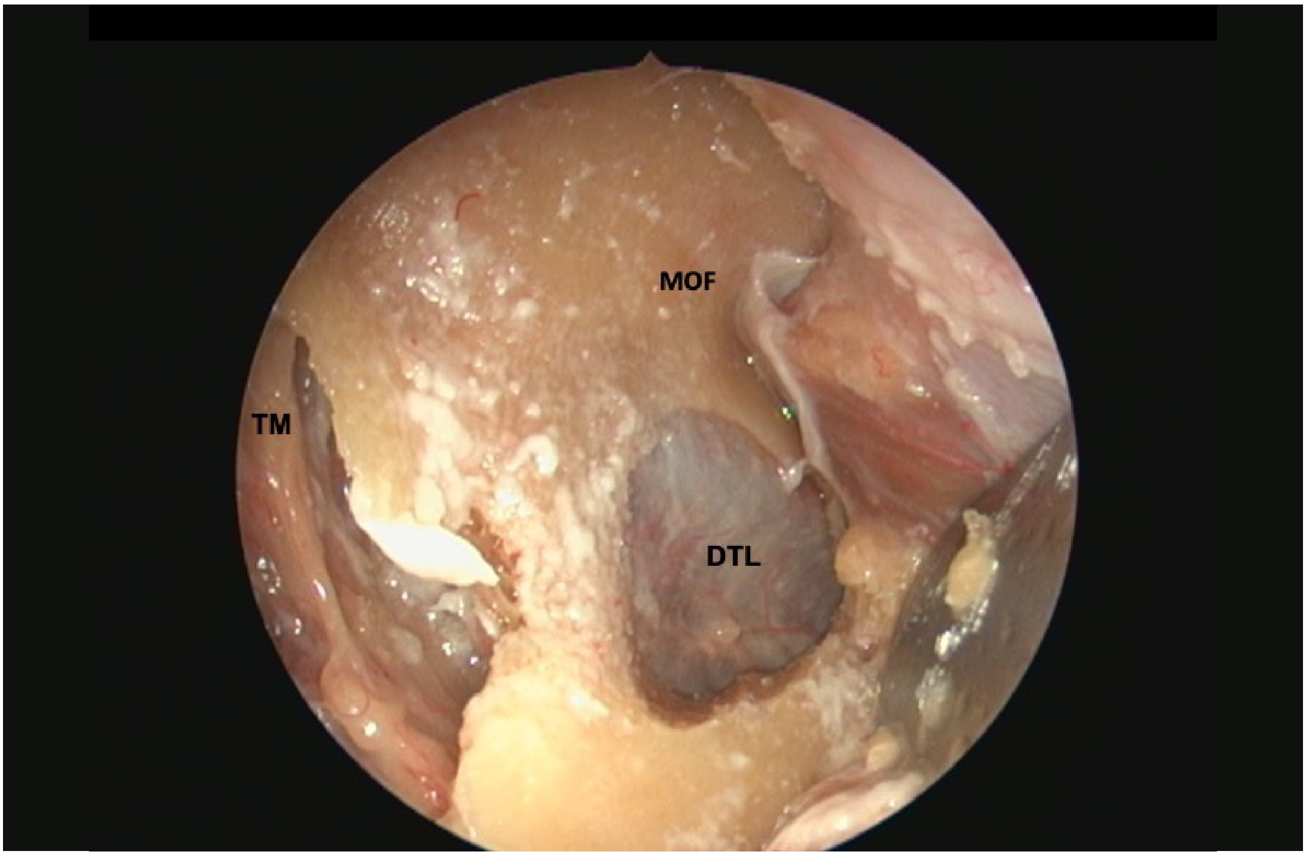

Fig. 2.- Right orbital cavity after drilling the lateral wall (zygomatic) and greater wing of sphenoid. TM: temporalis muscle; DTL: dura mater of temporal lobe; MOF: meningo-orbital foramen.

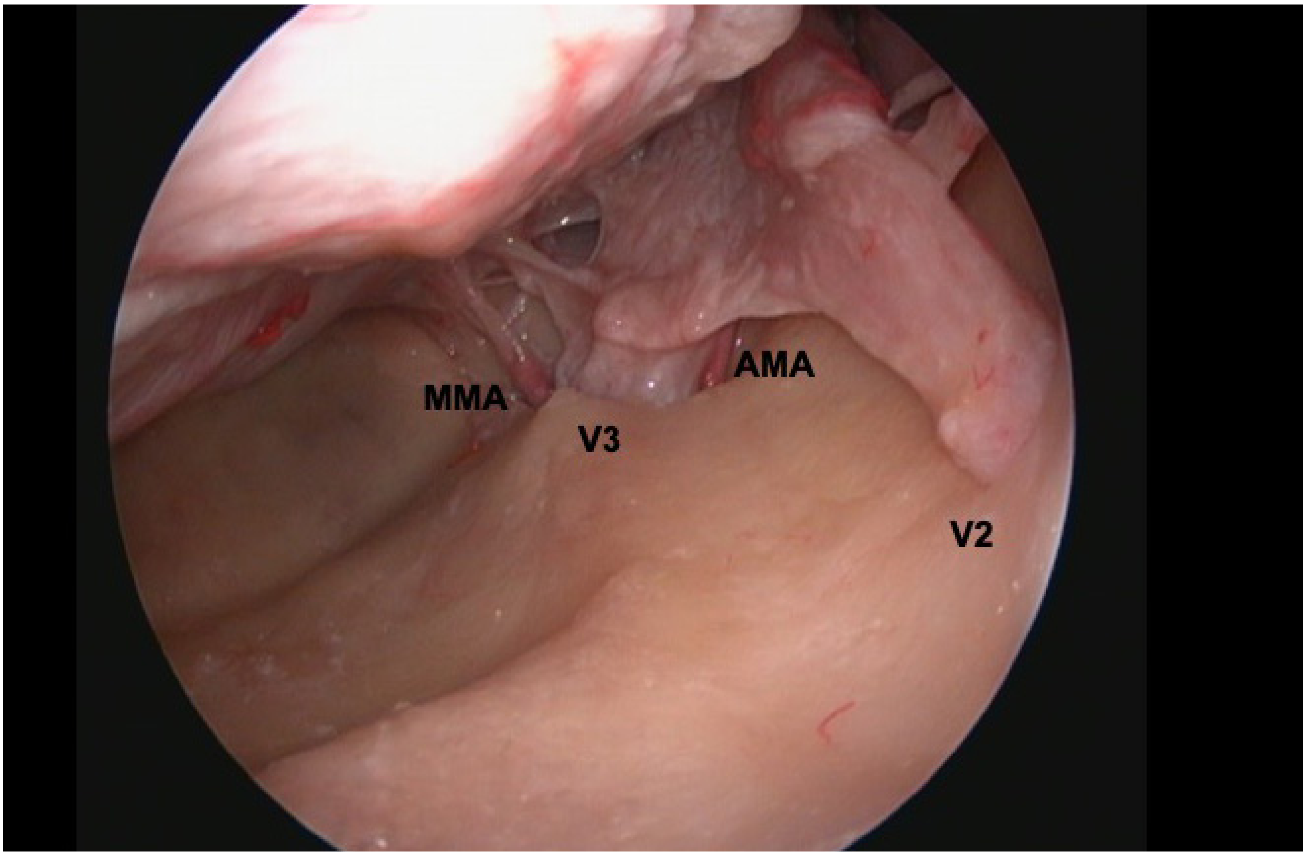

Fig. 3.- Floor of the right middle cranial fossa after subperiosteal elevation of the temporal lobe. V2: maxillary nerve; V3: mandibular nerve; AMA: accessory meningeal artery; MMA: middle meningeal artery.

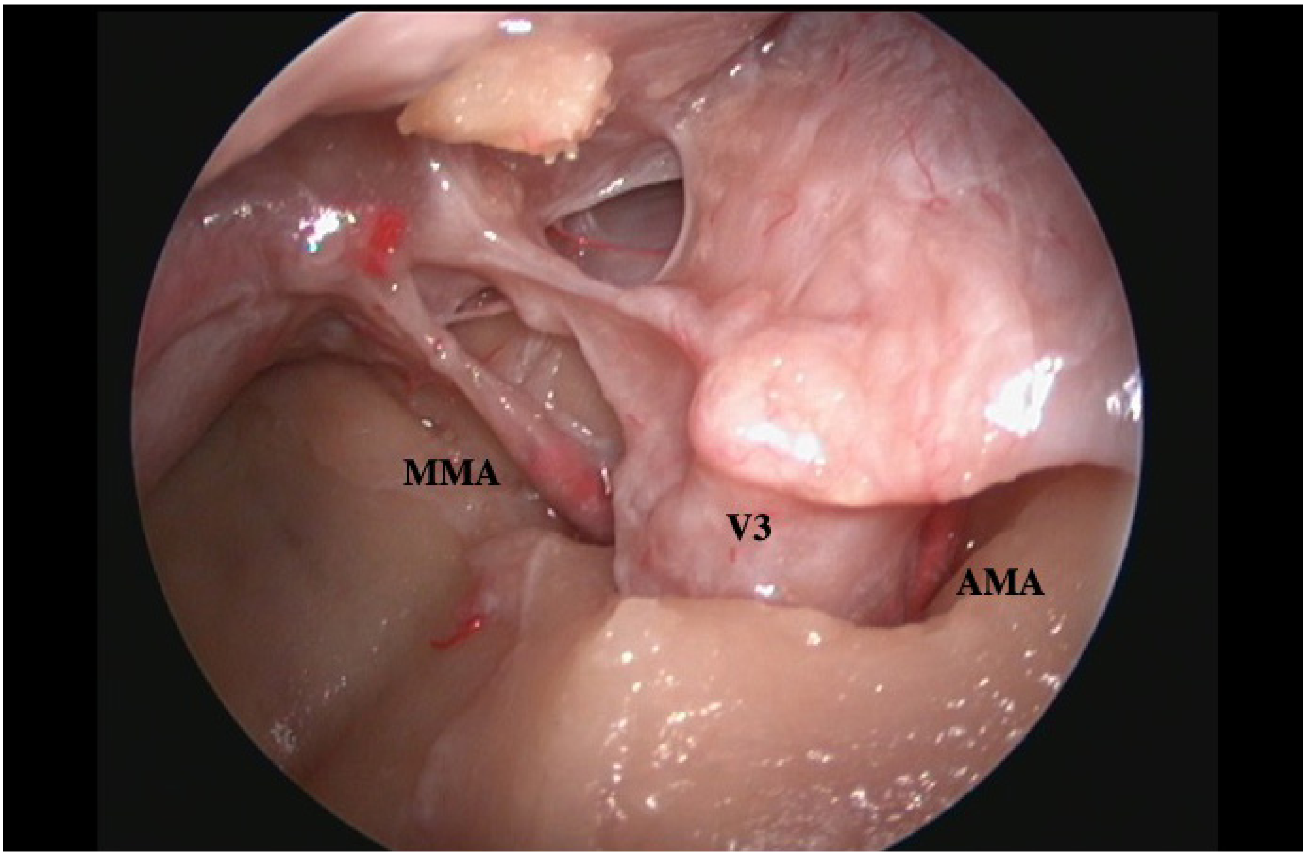

Fig. 4.- Floor of the right middle cranial fossa after subperiosteal temporal lobe elevation (deeper than Fig. 3). V3: mandibular nerve; AMA: accessory meningeal artery; AMM: middle meningeal artery.

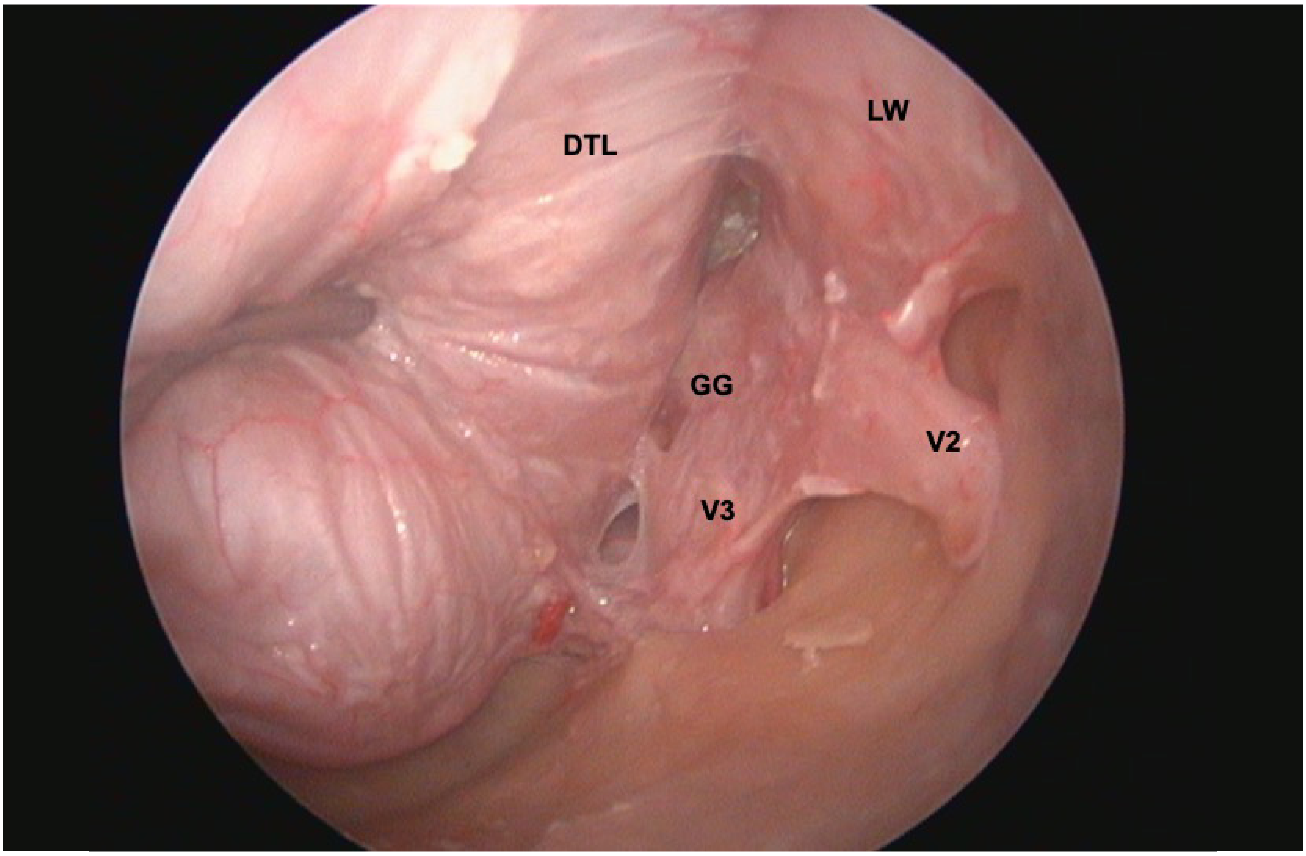

Fig. 5.- Approach to the lateral wall of the right cavernous sinus. DTL: dura mater of the temporal lobe; LW: lateral wall of the cavernous sinus; V2: maxillary nerve; V3: mandibular nerve; GG: Gasser ganglion.

meningo-orbital band, a structure that represents the fold between the periorbita and the dura mater of the temporal lobe. This reference allowed us to dissect the double layer that forms the lateral wall of the cavernous sinus (Fig. 5).

RESULTS

Dissection of the MCF. The mean distance from the zygomatico-facial foramen to the orbital rim was 11 mm (range: 10-20 mm) and 16 mm from the zygomatico-temporal foramen (range: 10-22 mm). In 100% of cases (12/12) the meningo-orbital foramen was found at a mean distance from the orbital rim of 34 mm (range 32-40 mm). The SOF was located posterior to the meningo-orbital foramen at a mean distance of 39 mm (range: 35-43 mm) from the orbital rim.

In all cases the foramen rotundum and foramen ovale were located separated from each other by 10 mm (range: 8-14 mm). In all dissections a bony prominence was located in front of the foramen ovale (Fig. 6).

In 11 cases (92%) the entrance of the AMA was evident within the foramen ovale anterior and/or medial to mandibular nerve (V3). In only one case an accessory foramen (Vesalius) was observed. The MMA was located in all dissections within the foramen spinosum.

Lateral wall dissection of the cavernous sinus. During dissection of the lateral wall of the cavernous sinus it was possible to identify the meningo-orbital band in all cases, as well as to locate the oculomotor nerves (III-IV) and the ophthalmic nerve (V1) in the internal (periosteal) layer (Fig. 7).

DISCUSSION

Endoscopic approaches using the orbit as a corridor are one of the most attractive new techniques in recent years. These approaches can be classified into orbital endoscopic, transorbital endoscopic and neuroendoscopic transorbital approaches (TONES) (Balakrishnan and Moe, 2011). The term TONES describes four access corridors, medial (precaruncular), lateral, inferior, and su-

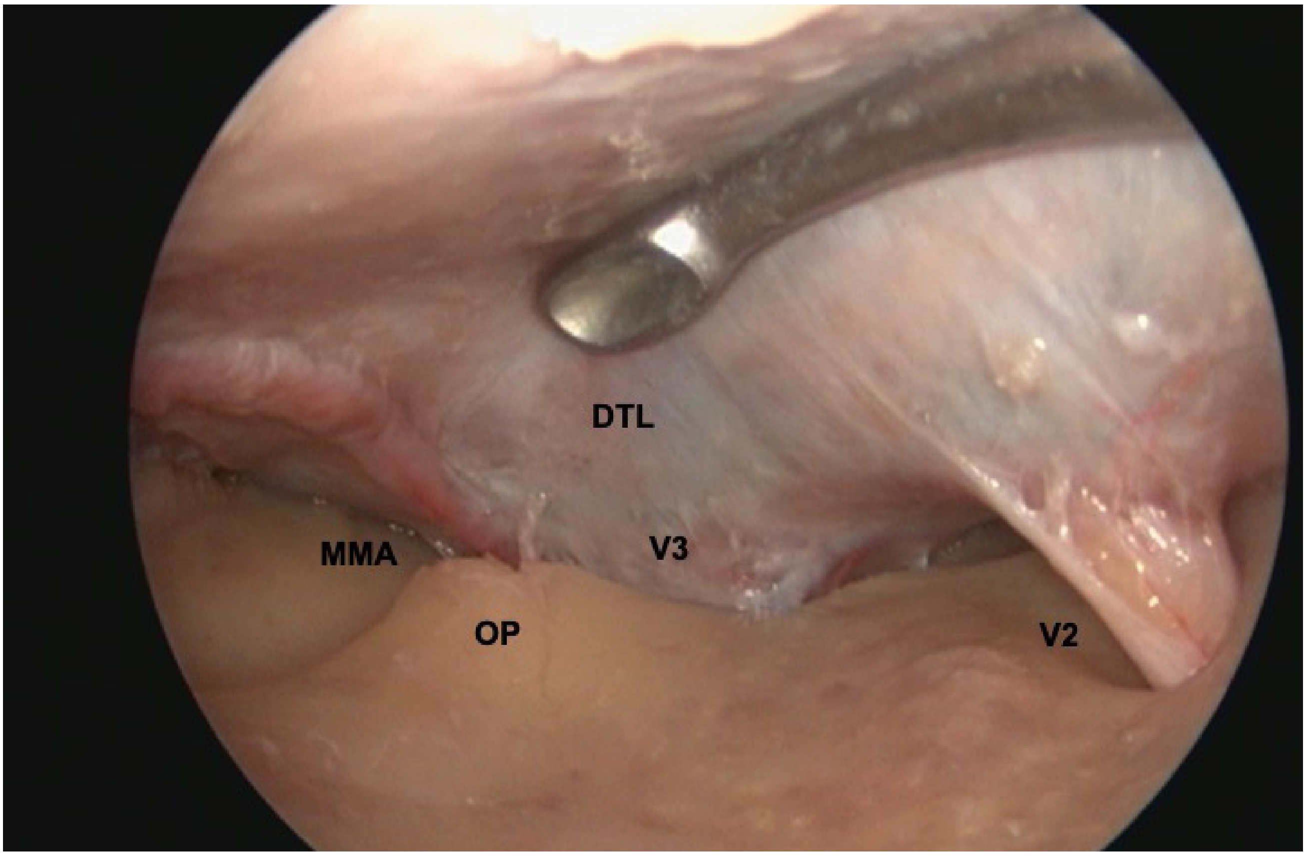

Fig. 6.- Visualization of the oval prominence (OP) on the floor of the right middle cranial fossa. DTL: dura mater of the temporal lobe; V2: maxillary nerve; V3: mandibular nerve; MMA: middle meningeal artery; PO: oval prominence.

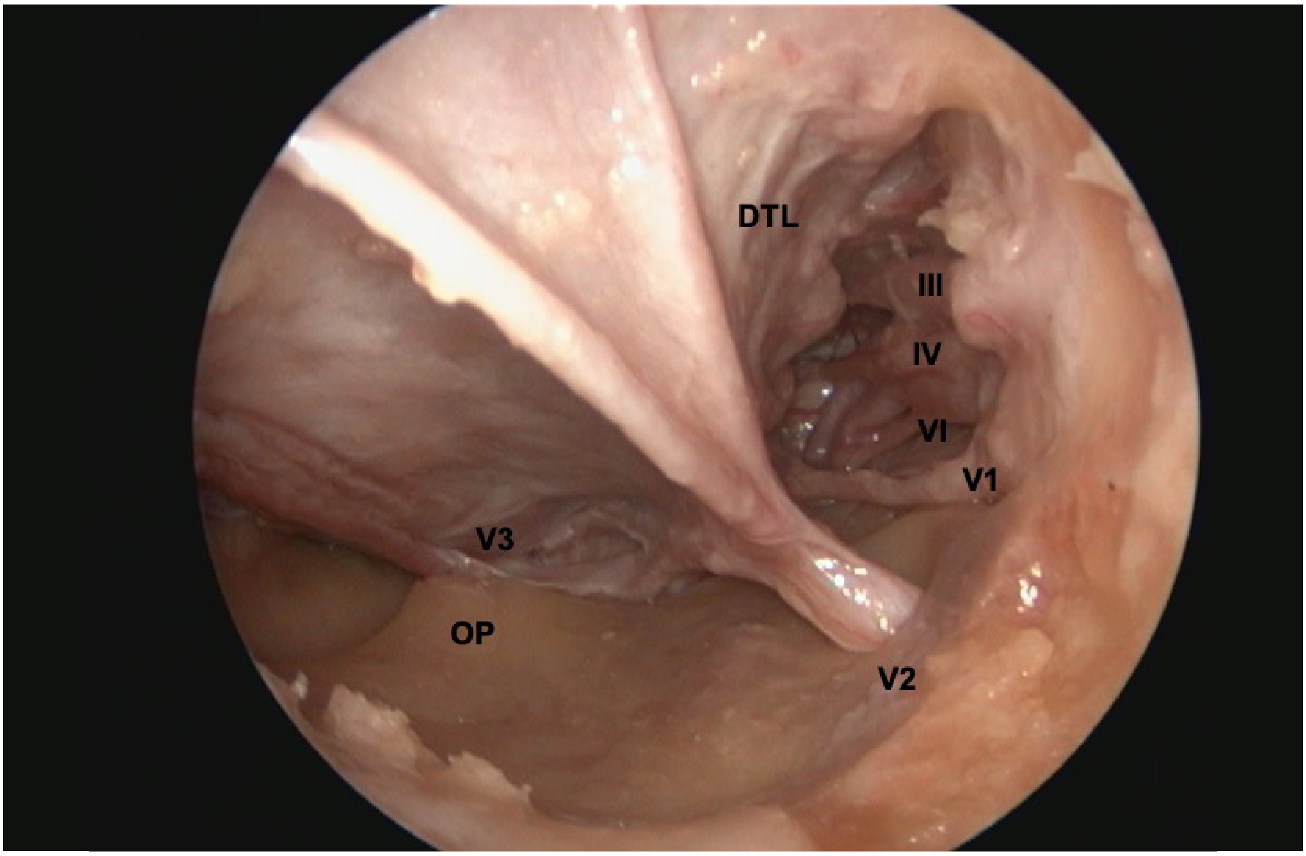

Fig. 7.- Lateral approach to the right cavernous sinus. DTL: dura mater of the temporal lobe; V2: maxillary nerve; V3: mandibular nerve; OP: oval prominence; Oculomotor nerves (III-IV-VI); V1: ophthalmic nerve.

perior. The lateral approach has the advantage of preserving the orbital rim without the need for reconstruction and avoids both craniotomy and traction of the brain contents. It also allows the palpebral fold to be used to minimise the possible cosmetic aspects caused by the scar. This technique can be used to treat certain lesions such as spheno-orbital meningiomas, osteomas, lesions on the lateral wall of the cavernous sinus, lesions of Meckel's cavum, vascular lesions and functional neurosurgical procedures (Andaluz et al., 2008; Abdel Aziz et al., 2011; Dallan et al., 2015; Lubbe et al., 2017; Di Somma et al., 2018; De Rosa et al., 2019; Suero Molina et al., 2021).

Our anatomical study shows in detail the different structures of the MCF that can be reached with an TTLEA, displacing the orbital contents medially without the need to open the periorbital cavity. The anatomical limits of this approach represent a triangular space defined superiorly and medially by the SOF, laterally by the temporalis muscle fascia and inferiorly and medially by the IOF (Fig. 1).

During dissection of the orbital lateral wall, we found foramina through which different structures enter and leave the orbit. On the anterolateral surface of the zygomatic bone we can see, through small bony ducts, the zygomatic-facial and zygomatic-temporal nerve branches. Both are branches of the zygomatic nerve which take their origin directly from the maxillary nerve in the pterygopalatine fossa. These nerves are accompanied by their arteries, which are branches from the lacrimal artery (ophthalmic artery). According to different studies, the zygomatic-temporal and zygomatic-facial vascular-nerve bundle are located approximately 4.3 mm to 9 mm away from the orbital margin (Krishnamurthy et al., 2011; Iwanaga et al., 2017, 2018). In our study, these measurements were located deeper than in the series reviewed. Both structures were located at an average distance of 11 mm and 16 mm, with the zygomatic-temporal foramen being located superior and posterior to the zygomatic-facial foramen. In depth, anterior to the lateral margin of the SOF, we can locate the meningo-orbital foramen (also called lacrimal, sphenofrontal, cranio-orbital or Hyrtl's orifice). The distance from the meningo-orbital foramen to the fronto-zygomatic suture is estimated to be between 25 mm and 31 mm (Macchi et al., 2016). It allows the passage of an anastomotic branch of the lacrimal artery to the MMA. Its prevalence is highly variable, ranging from 44 to 83%. In most cases it connects directly with the MCF and less frequently with the anterior cranial fossa (McQueen et al., 1995; Macchi et al., 2016). In our study, it was located in all cases at an average distance of 34 mm from the frontozygomatic suture, slightly more posterior than most of the data published in the different series. These differences and those found in the zygomatic vasculo-nerve bundles, can be explained by racial reasons or by differences in the measurement points at the level of the orbital rim. In our study they were calculated using the frontozygomatic suture as a reference. It is important to locate and cauterise all these small arteries that perforate the lateral orbital wall in order to safely advance the dissection in depth and to be able to reach the SOF. Its anterior margin is located approximately 34-41 mm from the lateral orbital rim (Dutton, 2011). Our data reflect a similar distance.

The MCF consists of the endocranial aspect of the greater wings of the sphenoid bone and the squamous and petrous parts of the temporal bone. The anterior margin of the floor of the MCF corresponds to the horizontal portion of the greater wing of the sphenoid which shows in the anterior-posterior direction, the foramen rotundum, the foramen ovale, the foramen spinosum, the foramen lacerum the trigeminal impression, the hiatuses for greater and lesser petrosal nerves and the arcuate eminence. In addition, two inconstant foramina can be found, the foramen venosum (sphenoidal emissary foramen or Vesalius' foramen) and the foramen petrosum (Arnold's foramen) (Rouvière and Delmas, 2005).

The foramen rotundum is located 3-4 mm posterior and inferior to the medial border of the SOF, and gives way to the maxillary nerve (V2), the foramen rotundum artery and small emissary veins (Rouvière and Delmas, 2005; Dutton, 2011; Gras Cabrerizo et al., 2017). It is the most anterior and medial structure located when performing subperiosteal dissection of the floor of the MCF.

Approximately 1 cm posterior and lateral to the foramen rotundum and 6 mm from Gasser's ganglion is located the foramen ovale (Rouvière and Delmas, 2005; Dutton, 2011). The main structures crossing the foramen ovale are the mandibular nerve (V3), the AMA, the lesser petrosal nerve and emissary veins (Kaplan et al., 2007). The AMA is present in more than 95% of cases as a branch of the first segment of the maxillary artery (mandibular segment) and in some cases may emerge directly from the MMA. It is predominantly an extracranial artery and only a small branch becomes intracranial, supplying the ganglion of Gasser and the dura mater of the FCM (Baumel and Beard, 1961; Dilenge and Géraud, 1975; Hur et al., 2012). This artery usually passes through the foramen ovale anterior or medial to the mandibular nerve(Baumel and Beard, 1961) (Figs. 3, 4). In 22% it may pass through the Vesalius' foramen (foramen venosum) located medial and anterior to the foramen rotundum (Tanoue et al., 2013; Leonel et al., 2020).

In the most of our cases, the AMA was located anterior and medial to the mandibular nerve (V3). Only in one case we found a foramen venosum. The location of the foramen ovale is an anatomical reference of great surgical relevance. Its identification makes it possible to safely approach lesions located in front of it, as both the internal carotid artery in its petrous portion and the pharyngotympanic tube are located posteriorly. In our study, we found a constant bony reference located anterior to the foramen ovale (oval prominence). This structure makes it possible to locate this foramen precisely and to preserve its contents. We have not found any reference to this anatomical structure in the series reviewed.

Approximately 3 mm posterior and lateral to the foramen ovale is placed the foramen spinosum, crossed by the middle meningeal artery (MMA) and vein and the meningeal branch of V3 (nervus spinosus). It may be absent unilaterally in 0.4% to 1% of cases (Krayenbühl et al., 2008). The MMA emerges from the first segment of the maxillary artery and, once is crosses the foramen spinosum, it divides into two branches (anterior and posterior). The anterior branch supplies the orbital region and the dura mater of the MCF, and can be anastomosed with the ophthalmic artery via the meningo-lagrimal artery through the meningo-orbital foramen (Rouvière and Delmas, 2005; Drake, 2011; Tanoue et al., 2013; Kornieieva et al., 2015).

The TTLEA has advantages over the classic approach using a pterional craniotomy alone or with its transzygomatic or orbitozygomatic variants (Drake, 2011). We avoid a skin incision in the frontotemporal region and a possible injury to the frontal branch of the facial nerve. It is not necessary to uninsert the temporalis muscle, thus avoiding discomfort at this level and the possible aesthetic defect due to atrophy of this muscle. Similarly, this pterional approach can also cause problems during mastication and at the temporomandibular joint.

To reach the most medial territory of this approach and thus to achieve the lateral wall of the cavernous sinus, it is necessary to locate and sectioning the meningo-orbital band. This anatomical structure represents the fusion of the fronto-temporal dura mater with the periorbita at the level of the lateral margin of the SOF. The transorbital approach allows to reach this structure without the need of retracting the temporal lobe if we compare with the frontotemporal approach. It is the anatomical reference that allows the cleavage plane to be found in order to perform an interdural dissection and separate the two layers that make up the lateral wall of the cavernous sinus, the external layer (dura mater) and the internal layer (periosteum) (Anania et al., 2022; Guizzardi et al., 2022). The external wall is thick while the inner layer is thin, semi-transparent and contains cranial nerves III, IV and V1. This procedure represents an alternative to the external approach with several advantages: a more direct and advantageous approach angle, no manipulation of the temporalis muscle and less manipulation of the temporal lobe and cranial nerves. Dallan et al. (2017) suggest its use for selected lesions such as trigeminal neurinomas and meningiomas lateral to the cavernous sinus. Our anatomical study provides relevant information for initiating these approaches and gaining greater experience.

The transpalpebral transorbital endoscopic lateral transorbital approach offers a wide and direct exposure of the MCF. It should be considered as an alternative to transcranial approaches in certain lesions invading the lateral region of the MCF, the lateral wall of the cavernous sinus or the infratemporal fossa. A detailed anatomical knowledge of the region is necessary to obtain the best surgical, aesthetic and functional results.

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