Dorello's canal: a microanatomical study

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The microsurgical anatomy of Dorello's canal has been studied in 20 specimens obtained from 10 cadaver heads fixed in formalin. The bow-shaped canal through which courses the abducens nerve before reaching the cavernous sinus is located inside a venous confluence which occupies the space between the dural leaves of the petroclival area. The petrosphenoidal ligament (Gruber's ligament), which forms the posteromedial wall of the canal, appears as a fibrous trabecula surrounded by venous blood. Canal measurements were performed and its anatomical relationship with the sixth cranial nerve is described. Angulations of variable degrees were observed in the course of the nerve inside and outside the canal. The influence of this relatively tortuous course of the abducens nerve upon its vulnerability in some pathological conditions is discussed.

KEY WORDS • abducens nerve • Dorello's canal • petrous apex • anatomical study

The anatomical relationships of the abducens nerve with the petrous apex in the petroclival region are of clinical interest. The relatively fixed position of the nerve within an osteofibrous compartment known as “Dorello’s canal” makes it particularly vulnerable to several pathological conditions. Head injuries with or without fractures of the base of the skull, space-occupying lesions with shifting of the brain stem, surgical trauma, inflammatory disease of the petrous apex (Gradenigo’s syndrome), internal carotid artery (ICA) aneurysms, and sphenoid sinus pathology among others may injure the nerve causing paralysis of the external rectus muscle. Recent advances in surgical techniques to approach the skull base have revived an interest in the study of the microsurgical anatomy of this complex region.

From our series of cadaver dissections we have observed variations in the anatomy of Dorello’s canal and in the course of the abducens nerve that might influence the vulnerability of the nerve. To our knowledge no microanatomical study of Dorello’s canal has been performed previously.

Materials and Methods

Ten cadaver heads (20 specimens) fixed in formalin were dissected for this study. The heads were placed in a Sugita head holder, turned 45° from the side of dissection and extended slightly to simulate the surgical position. A frontotemporal craniotomy was performed and the zygomatic arch together with part of the superior and lateral orbital walls was divided and removed. With the aid of the operating microscope, the dura mater was dissected beginning at the floor of the middle fossa from posterior to anterior and from lateral to medial. The bone forming the floor of the middle cranial fossa was removed, exposing the lateral aspect of the superior orbital fissure, the foramen rotundum, the foramen ovale, and the foramen spinosum. The horizontal portion of the petrous ICA was exposed and further medial retraction of the dura mater revealed Meckel’s cave and the point of entry of the ICA into the inferior wall of the cavernous sinus. The abducens nerve was identified at the point where it crossed the lateral wall of the artery and was followed backward toward Dorello’s canal. Further dissection in this area disclosed the petrosphenoidal ligament, the petrous apex, the venous confluence in the upper part of the clivus, and the opening of the inferior petrosal sinus. The configuration, measurements, and contents of Dorello’s canal were studied. Special attention was given to the presence of angulations in the course of the sixth cranial nerve within and in close proximity to the canal. Thereafter, the brain was carefully removed in order to fully expose the skull base, and further anatomical data were recorded.
Anatomical Observations

Dorello's canal is an osteofibrous conduit located at the level of the petrous apex through which the abducens nerve courses to reach the cavity of the cavernous sinus. It was a well-defined space in every specimen studied and had a bow-shaped configuration. The canal is located inside a venous confluence which occupies the space between both dural leaves (outer or endosteal and inner or cerebral) of the petroclival area. The venous channels joining this confluence are: the posterior part of the cavernous sinus, the inferior petrosal sinus, and the basilar sinus (Fig. 1). Because of this particular anatomical arrangement, the petrosphenoidal ligament appears as a fibrous trabecula immersed in venous blood. In some specimens we found the cavity of the venous confluence being crossed by several trabeculae among which the petrosphenoidal ligament (Gruber's ligament) can always be identified by its largest size, its strength, and its silvery appearance.

Canal Boundaries

The anterolateral wall of Dorello's canal is slightly curved with a posterior concavity. It is formed by the most anterior part of the superior border of the petrous bone, the upper part of the petrosphenoidal suture, and the lateral part of the upper clivus below the dorsum sellae and posterior clinoid process. The bone in this area is covered by the endosteal layer of the dura mater. The posteromedial wall of the canal corresponds to the petrosphenoidal ligament or Gruber's ligament. This ligament extends from the spina sphenoidalis located on the superior border of the petrous apex to the lateral border of the dorsum sellae and clivus (Fig. 1). The ligament was found to have a butterfly shape, being wider at its medial (mean ± standard deviation: 4.58 ± 2.2 mm) and lateral (4.38 ± 1.8 mm) insertions and narrow at its midpoint (2.75 ± 1.3 mm). Its mean length was 12.27 ± 2.2 mm. The ligament was duplicated in one case (Fig. 2), ossified in another (Fig. 3), and hypoplastic in a third.

Canal Measurements

In this study the diameter of Dorello's canal varied from 0.5 to 3.0 mm (mean 1.5 ± 0.8 mm) and its length from 4.0 to 13 mm (mean 9.22 ± 2.2 mm).

Canal Contents

The canal, filled with the venous blood of the previously described venous confluence, contained the abducens nerve in 100% of the specimens and the dorsal meningeal branch of the meningo-hypophyseal trunk in 80% of the cases (Figs. 1 and 3). This vessel contributes to the vascularization of the nerve. In three specimens the dorsal meningeal artery divided into two branches: one coursing beneath the nerve. The others were ossified within the petrosphenoidal ligament (Fig. 1). The ostium of the inferior petrosal sinus was found within the venous confluence, either lateral (80%) or medial (20%) to the sixth cranial nerve. It was located below Gruber's ligament and outside Dorello's canal in all cases (Fig. 1).

The most frequent location of the abducens nerve inside Dorello's canal was in its middle third (in 52% of specimens, Fig. 2). In 39% of cases the nerve was located in the outer third, and in 9% in the inner third of the canal.

In three specimens there was a duplication of the sixth nerve in its course through the canal (Fig. 4). Inside Dorello's canal the abducens nerve was tightly
attached to the endosteal dura of the petrous apex and to Gruber's ligament by connective tissue intimately related to the dural sheath surrounding the nerve in this region.

Angulations of variable degrees were observed in the course of the nerve inside and outside the canal. The first change in direction occurs where the nerve pierces the dura mater to enter the extradural or "interdural space." This angle is usually obtuse and opens medially and upward (Fig. 1). A second and more significant angulation is present at the level of the petrous apex. Here, the nerve may change its direction rather abruptly, describing an angle close to 90° directed downward and laterally (Fig. 4). The third and last change in direction is found where the nerve leaves Dorello's canal to reach the ICA at the level of the inferior wall of the cavernous sinus. This angulation depends on the position and diameter of the artery and usually less is pronounced (Fig. 5).

Anatomical Variations

Changes in the canal configuration were due mainly to anatomical variations of Gruber's ligament. In one case the ligament was almost completely ossified and the sixth nerve was coursing through a bony canal (Fig. 3). In another specimen, the ligament was hypoplastic, thin, and transparent. In yet another case, the ligament was duplicated (Fig. 2).

Discussion

In 1859, Gruber,12 described the presence of an osteofibrous canal at the apex of the petrous bone which he called the "foramen petro-sphenoidem." This "foramen" measured 6 to 12 mm in length and 1 to 3 mm in width and contained the abducens nerve and the inferior petrosal sinus. In most of his specimens, the posterior wall of the foramen was formed by the "ligamentum petro-sphenoidem or sphen-petrosum posterior," but in 1% to 2% of the examined skulls the ligament was ossified, a feature he found normal in some species of apes (Simia satyrus).

Dorello10 in 1905, stimulated by Gradenigo's work on abducens nerve palsy in cases of inflammatory lesions of the petrous apex,11 studied the anatomy of this region. He suggested that the most probable mechanism...
Dorello's canal

Fig. 4. Cadaver specimen (left) and artist's drawing (right), superior view, of a right Dorello's canal showing the duplication of the abducens nerve (VI) and its acute angulation at the apex of the petrous bone (PA). The arrow indicates Gruber's ligament; ICA = internal carotid artery. PLL = petrolingual ligament. Scale in millimeters.

of the nerve palsy in those cases was compression of the sixth nerve by the petrophenoidal ligament of Gruber. The first description in the English literature of Dorello's anatomical findings was by Vail in 1922, who added the results of his own studies performed in eight specimens, including one fetus of 8 months. He found that inside the canal the abducens nerve was in a lateral position, the meningeal artery was in a medial position, and the inferior petrosal sinus usually overlay the nerve.

Since these early anatomical descriptions, the osteofibrous canal, now called "Dorello's canal," has become a reference point and is frequently cited to describe the anatomical bases of sixth cranial nerve lesions in different pathological conditions. Several mechanisms have been implicated to explain the vulnerability of the abducens nerve: its long intracranial course, strangulation by transverse branches of the basilar artery, pressure against the sharp upper border of the petrous apex, and compression by Gruber's ligament among others. Arias, described two points of dural fixation in the course of the sixth nerve: one at its entrance and one at its exit from the extradural space. He agreed with the mechanism of injury proposed by Takagi et al., in which the rigid dural hole located at the point of entrance of the nerve into the extradural space acts as a fulcrum, so that the nerve is injured against the ridge of the petrous pyramid in cases of a severe midfrontal impact.

In our anatomical dissections we found that the main point of fixation of the abducens nerve is inside Dorello's canal. Here, dense adhesions exist between the dural sheath of the nerve, the endosteal dura of the petrous apex, and the petrophenoidal ligament (Gruber's ligament). The angulation of the sixth cranial nerve on its way toward the superior orbital fissure and its fixation inside the relatively narrow Dorello's canal may result in compression and stretching injuries of the nerve in cases of brain-stem shifting due to expanding lesions and intracranial hypertension. This might damage the nerve fibers either directly or by interference with their blood supply.

Some contradictory descriptions can be found in the literature regarding the boundaries of Dorello's canal. The classic works defined the canal as the small space located between the petrous apex and Gruber's ligament. Other authors have described it as a larger space located between the two dural leaves and extending from the point where the abducens nerve pierces the dura mater to its entrance in the cavernous sinus.

We believe that the difficulty in defining the canal in terms of its anatomical limits lies in the original descriptions by Gruber and Dorello, who included the inferior petrosal sinus inside the canal. In our study, we found that the sinus opened in close proximity to but never

Fig. 5. Cadaver specimen (left) and artist's drawing (right), posterior view, of a right Dorello's canal. Gruber's ligament (GL) has been cut and reflected laterally. The abducens nerve (VI), lying inside a tight canal, is compressed by the ligament and is describing a lateral opening angle before reaching the lateral wall of the intracavernous internal carotid artery (ICA). The opening of the inferior petrosal sinus (arrow) can be seen inferiorly and laterally to Dorello's canal. BS = basilar sinus; VN = trigeminal nerve. Scale in millimeters.
within the osteofibrous channel itself. Thus, we agree with the classic description of the canal boundaries but emphasize the fact that it is located inside a large dural space occupied by a venous confluence into which the inferior petrosal sinus opens and in which Gruber's ligament represents a large fibrous trabecula.

References


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