Dorello Canal Revisited: An Observation that Potentially Explains the Frequency of Abducens Nerve Injury After Head Injury

R. Shane Tubbs¹, Virginia Radcliff¹, Mohammadali M. Shoja², Robert P. Naftel¹, Martin M. Mortazavi¹, Anna Zurada³, Marios Loukas⁴, Aaron A. Cohen Gadol⁵

INTRODUCTION

The abducens nerve travels a long intracranial course, and as a result it is commonly injured after head trauma. The abducens nerve can be divided into five segments: three are intracranial (cisternal, gulfar, and cavernous) and two are orbital (fissural and intraconal) (5).

Along its midway course, the abducens nerve travels in Dorello canal, which has controversy in the literature regarding its boundaries. Dorello (4) and Gruber (7) described the canal as lying between the apex of the petrous bone and the petrosphenoidal ligament (Gruber ligament) (Figure 1). Dolenc (3) described the canal as beginning from the entrance of the abducens nerve at the dura covering the clinus to the cavernous sinus. Umansky et al. (15) described the posteromedial wall as consisting of Gruber ligament, yet Destrieux et al. (2) used this ligament as the roof of the canal.

Besides the abducens nerve, and depending on the definition used, the dorsal meningeal artery and inferior petrosal sinus travel in Dorello canal. As an example of how various definitions of this canal can affect what contents are included within its confines, Umansky et al. (15) did not include the inferior petrosal sinus within this space.

Because the abducens nerve may become trapped within Dorello canal (10) and is commonly injured after head injury, the present study aimed to further elucidate its arrangement in this region.

MATERIALS AND METHODS

For the present study we chose to define Dorello canal as beginning at the dural entrance of the abducens nerve (i.e., petrosphenoidal or gulfar segment) to its entrance into the cavernous sinus (Figure 1). Twelve fresh adult cadavers (24 sides), aged 47–81 years at death (mean 75 years) and latex injected, underwent microsurgical dissection of the skull base at Dorello canal.
specimens were male and five specimens were female. An oscillating bone saw was used to remove the calvaria and then the supratentorial brain was removed, taking care not to disrupt any infratentorial structures. Under direct vision, motion of the abducens nerve with manipulation (e.g., posterior, lateral, inferior displacement) of the intact brainstem was performed observing for any movement within Dorello canal before and after transection of Gruber ligament. Next, using a surgical microscope (Zeiss; Germany), dissection of the entrance of the abducens nerve into Dorello canal was performed. The meningeal layer of dura mater covering the dorsal clivus was opened anteriorly to the cavernous sinus, and observations were made of relationships of the abducens nerve in this region. Again, movement of the brainstem was performed and observations made of the abducens nerve after sequential transection of the overlying dura and inner meningeal tube.

RESULTS

No specimen was found to have intracranial pathology in the region dissected. In all specimens, a secondary tunnel (i.e., tube within a tube) was found within Dorello canal that exclusively contained the abducens nerve (Figures 2-4). This structure rigidly fixated the abducens nerve as it traversed Dorello canal, thereby not allowing movement. Transection of Gruber ligament or overlying clival dura did nothing to detach the nerve, but after the opening of the inner tube, the nerve was easily mobilized within Dorello canal. The basilar venous plexus and inferior petrosal sinuses were all external to the inner meningeal tube, as was the dorsal meningeal artery and its branches. One right-sided specimen was found to have two separate dorsal meningeal branches with the more lateral branch accompanying the abducens nerve within Dorello canal, but again, external to the inner dural tube. Each inner tube within Dorello canal intimately surrounded the abducens nerve throughout the entire canal but did not compress the nerve. These internal tubes maintained the abducens nerve within the medial aspect of Dorello canal.
DISCUSSION
Cranial nerve entrapment neuropathies may be due to edematous pressure, venous congestion, arterial compression that may respond to microvascular decompression, lymphatic stasis at extracranial exit sites, bony impingement, membranous tension, or ligamentous pull \( (\text{to}) \).

Ono et al. \( (\text{to}) \) mentioned briefly that the petroclival segment of the abducens nerve was covered by an envelope composed of an arachnoid cell layer. Destrieux et al. \( (\text{to}) \) appreciated this arrangement but observed it inconstantly. Tsitsopoulos et al. \( (\text{to}) \) found such an envelope in all of their specimens and commented that such an envelope isolated the abducens nerve from the inferior petrosal sinus within Dorello canal, and our findings concur with this. Destrieux et al. \( (\text{to}) \) defined the “petrovenous gulf” (PVG) as a venous space bordered by endothelium and continuous with the cavernous, basilar, and inferior petrosal sinuses. Gruber ligament has been regarded by some investigators as dividing the PVG into superior and inferior compartments with the abducens nerve, generally, traveling through the inferior compartment, where it was fixed to the surrounding dura mater. We found an inner meningeal tube surrounding the abducens nerve within Dorello canal in all specimens. This morphology separated the nervous from venous structures within Dorello canal. Such anatomy is reminiscent of the relationship seen in the jugular foramen with a medial pars nervosa and a lateral pars venosum. In cadavers, Ozveren et al. \( (\text{to}) \) found an arachnoid membrane on the clivus that extended within the dural sleeve surrounding the abducens nerve as far as the petrous apex. The average length of the dural sleeve, described by them, was 9.5 mm and the average width was 1.5 mm at the apex, where the nerve entered the cavernous sinus. They \( (\text{to}) \) found that the subarachnoid space inside the dural sleeve of the abducens nerve can be defined by using thin-slice magnetic resonance imaging scans and that enlargement of the dural sleeve at the petroclival region may coexist with abducens nerve palsy.

A dolichoectatic vertebral artery \( (\text{to}, \text{9}) \) and anterior inferior cerebellar artery \( (\text{to}) \) have been implicated in isolated abducens nerve palsies, which may be transient. Linn et al. \( (\text{to}) \) have suggested a neurovascular compression syndrome involving the abducens nerve. Similarly, De Ridder and Menovsky \( (\text{to}) \) noted intermittent abducens nerve palsy from a dolichoectatic basilar artery that was successfully treated with microvascular decompression. Sandvand et al. \( (\text{to}) \) reported an adult with right-sided intermittent abducens nerve palsy due to vascular compression of the abducens nerve at its root exit zone by the anterior inferior cerebellar artery. In each of these cases, tethering of the abducens nerve as it enters a separate tunnel within Dorello canal, may contribute to this nerve’s sensitivity because there is no “give” from mass effect such as from an ectatic vascular structure.

Based on our findings, abducens nerve compression would not be relieved by simply opening of Dorello canal. In addition, the inner meningeal tube needs to be opened to decompress the nerve. Manipulation of the abducens nerve near the PVG, as described by Destrieux et al. \( (\text{to}) \), would necessitate opening of the inner meningeal tube.

CONCLUSIONS
Mobility of the abducens nerve within Dorello canal is strictly limited due to the inner meningeal tube surrounding this nerve. This finding may elucidate the mechanism for the frequency of abducens nerve palsy after head trauma. In addition, such information may assist neurosurgeons who operate in or near the cavernous sinus or Dorello canal.

REFERENCES

Conflict of interest statement: The authors declare that the article content was composed in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.