Duplicated abducent nerve and its course: microanatomical study and surgery-related considerations

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Object. The anatomy of the abducent nerve is well known; its duplication (ranging from 5 to 28.6%), however, has rarely been reported in the literature. The authors performed a microanatomical study in 100 cadaveric specimens (50 heads) to evaluate the prevalence of this phenomenon and to provide a clear anatomical description of the course and relationships of the nerve. The surgery-related implications of this rare anatomical variant will be highlighted.

Methods. The 50 human cadaveric heads (100 specimens) were embalmed in a 10% formalin solution for 3 weeks. Fifteen of them were injected with colored neoprene latex. A duplicated abducent nerve was found in eight specimens (8%). In two (25%) of these eight specimens the nerve originated at the pontomedullary sulcus as two independent trunks: in one case the superior trunk was thicker than the inferior and in the other it was thinner. In the other six cases (75%) the nerve originated as a single trunk, splitting in two trunks into the cisternal segment; in two of them the trunks ran below the Gruber ligament, whereas in four specimens one trunk ran below and one above it. In all the specimens, the duplicated nerves fused again into the cavernous sinus, just after the posterior genu of the internal carotid artery.

Conclusions. Although the presence of a duplicated abducent nerve is a rare finding, preoperative magnetic resonance imaging should be performed to rule out this possibility, thus tailoring the operation to avoid postoperative deficits.

KEY WORDS • abducent nerve • Dorello canal • Gruber ligament

In the last two decades, because of the improvements of microsurgical procedures in petroclival and cavernous sinus surgery, well-detailed studies on the anatomical variations of cranial nerves have been performed. Abducent nerve anatomy is well known, and the duplication of the nerve is a rare finding. In 1974 Nathan, et al., and Lang described a duplicated abducent nerve, respectively, in 7.5% and 5% of their specimens. The incidence of duplication has been reported in the literature to range from 5 to 28.6%.

Nathan, et al., identified three basic patterns of abducent nerve course. In Pattern 1 (86.5%), the nerve originated from one or more small rootlets and merged immediately into a single trunk that reached the lateral rectus muscle. In Pattern 2 (6%), the nerve, after originating as a single trunk, split into a superior and inferior branch in its cisternal course; they pierced the dura mater separately, with a distance between the two points of piercing that varied from 2 to 4.5 mm; then, the two branches fused again in the cavernous portion. In Pattern 3 (7.5%), the nerve originated as two separate trunks fusing again into the cavernous sinus. Testut and Jain had previously described another anatomical variation in which the nerve originated as two branches that ran their full course independently.

Bilateral duplicated abducent nerves were found in 1.6% of Jain’s specimens. Uni- or bilateral absence or presence of three separated trunks has also been reported.

The aim of this microanatomical study is to provide a clear description of duplicated abducent nerve, defining its course and its relationship with other structures (the ICA, Gruber ligament, and AICA) and underlining the surgery-related implications of this rare finding.

Materials and Methods

One hundred human cadaveric specimens (50 heads) were examined. The specimens were embalmed in a 10% formalin solution for...
3 weeks. The specimens were held in a three-point rigid head holder fixed to a laboratory bench top. To expose the entire length and course of the abducent nerve, the following approaches were undertaken: the frontotemporal (with anterior clinoid drilling), anterior and posterior subtemporal (to remove the tentorium cerebelli), and the Kawase and preretrosigmoid. The superior orbital fissure and orbit were also opened to follow the terminal branches of the nerve. The cavernous sinus was opened by removing the thick outer membrane. The third, fourth, and sixth cranial nerves came into view in the lateral wall of the cavernous sinus. The thin inner membrane was opened, and abducent nerve was reflected laterally and inferiorly to disclose its course into the cavernous sinus. The nerve was followed distally into the orbital cavity and proximally into the so-called sphenopetroclival venous gulf, which is an irregularly pyramidal venous space filled by the blood arising from the cavernous sinus anteriorly, the basilar plexus medially, and the superior petrosal sinus laterally, draining into the inferior petrosal sinus. In intracranial dissection was performed under optic magnification. Measurements of the nerve segments were made using a millimeter paper. Photographs were obtained.

Results

A duplicated abducent nerve was found in eight (8%) of 100 specimens: five (62.5%) on the right side and three (37.5%) on the left (Fig. 1 left). In two cases (25%), the nerve originated at the pontomedullary sulcus as two independent trunks: one with the superior trunk thicker than the inferior, and one with the superior trunk thinner than the inferior (Fig. 1 right). In both cases, the trunks penetrated the sphenopetroclival venous gulf by passing below the Gruber ligament (Fig. 2 upper). In one specimen, the AICA was found to be duplicated, with a branch passing between the two nerve trunks (Fig. 2 lower). In the other six cases (75%), the nerve originated as a single trunk, splitting into two trunks in the cisternal segment (Fig. 3); in two of them, both trunks ran below the Gruber ligament, whereas in four specimens one trunk ran below and one above it. In all the specimens, the duplicated nerves fused into the cavernous sinus, at the level of the horizontal portion just after the posterior genu of ICA (Fig. 4).

The mean lengths and widths of duplicated abducent nerves, both those of double and single origin, are summarized in Table 1.

In the two specimens of double origin, the mean length of the nerve from the origin to the dural pore (cisternal segment) was 19 mm (range 18–20 mm) for the thicker trunk and 18 mm (range 17–19 mm) for the thinner one; 5 mm (range 3–7 mm) in the Dorello canal; 12.2 mm (range 10.8–14.1 mm) from the dural pore to the posterior bend of the carotid artery (venous segment); 14.3 mm (range 13.7–15.5 mm) from the posterior bend to the point of fusion; 26 mm (range 24–28 mm) from the posterior bend to the superior orbital fissure (cavernous segment); 2.5 mm (range 2–3 mm) in the fissural segment; and 12 mm (range 11–13 mm) from the superior orbital fissure to the division in terminal branches.

The width also varied in all the segments. The cisternal portion measured 0.9 mm (range 0.7–1.1 mm) for the thicker nerve and 0.3 mm (range 0.2–0.4 mm) for the thinner one. The venous segment measured, respectively, 1.2 mm (range 1–1.4 mm) and 1 mm (range 0.9–1.1 mm); the segment between the sphenopetroclival venous gulf and the posterior bend of the ICA, 1.1 mm (range 0.9–1.3 mm) and 0.5 mm (range 0.4–0.6 mm); the portion on the lateral wall of the posterior bend, 2 mm (range 1.8–2.2 mm) and 1 mm (range 0.9–1.1 mm); and the intracavernous segment before the fusion, 1 mm (range 0.9–1.1 mm) and 0.4 mm (range 0.3–0.5 mm). After the point of fusion, the...
mean width was 1.1 mm (range 1–1.2 mm). The nerve measured 1.2 mm (range 1.1–1.3 mm) in the superior orbital fissure, 1.1 mm (range 1–1.2 mm) in the orbit, and 1.9 mm (range 1.7–2.1 mm) just before the terminal branches.

In the six cases the nerve was of a single origin, the mean length was 15.6 mm (range 14.7–16.9 mm) for the cisternal segment, 11.5 mm (range 10.9–12.7 mm) for the venous segment, 26.3 mm (range 25.5–27.1 mm) for the cavernous portion, 2.6 mm (range 2.4–2.8 mm) for the fissural, and 11.4 mm (range 11.2–11.7 mm) for the intracanal segment.

The mean width of the nerve from the root exit zone to the bifurcation in the cisternal portion was 1 mm (range 0.9–1.1 mm); after the bifurcation, the thicker trunk measured 0.7 mm (range 0.5–0.9 mm) and the thinner trunk measured 0.3 mm (range 0.2–0.4 mm). The venous segment had a mean width of 1.2 mm (range 1.0–1.4 mm) for the thicker trunk and 1 mm (range 0.9–1.1 mm) for the thinner. In the cavernous sinus, the trunks measured, respectively, 1.2 mm (range 1.1–1.4 mm) and 0.8 mm (range 0.6–1.0 mm), whereas the fused trunk had a mean width of 1.2 mm (range 1.1–1.3 mm). The fissural segment measured 1.2 mm (range 1.1–1.4 mm) and the intracanal was 1.1 mm (range 1.0–1.2 mm).

**Discussion**

The anatomy, course, and blood supply of the abducent nerve are well known.

We considered the abducent nerve to be divided into five segments: 1) cisternal, from the pontomedullary sulcus to the posterior fossa inner dura; 2) venous, from the dura to the posterior genu of intracavernous ICA, into the
The cisternal segment of the abducent nerve forms a relationship with the AICA; the nerve runs on the posterior surface of the artery in 79% of cases and below it in 16%, and in 5% of specimens the AICA runs between two abducent nerve bundles. The cisternal segment of the nerve is usually flattened with anterior and posterior surfaces. The nerve becomes venous after piercing the dura; indeed, it traverses a pore in the clival dura, entering the sphenopetroclival venous gulf, passing through the canal of Dorello. The dural pore of the nerve lies approximately 6 mm below the trigeminal pore and approximately 13 mm medial to the medial rim of the internal porus acusticus. At the dural pore the nerve turns medially, forming the dural genu (first genu). The nerve then runs below the Gruber ligament into the Dorello canal, turning laterally and forming the petrous genu (second genu). At this point the nerve is situated just below and medial to the bony spur where the Gruber ligament inserts, which we call the “petrous tubercle.” This tubercle represents the petrous insertion of the Gruber ligament at the medial border of the Meckel cavity, and in 80% of cases it is particularly redundant. The venous segment becomes cavernous at the posterior bend of the intracavernous ICA, turning medially to form the carotid genu (third genu). Here the nerve is firmly adherent to the ICA. The cavernous segment of the nerve runs from the posterior genu of the ICA to the superior orbital fissure to become intrafissural. The fissural segment makes a laterally open, acute angle because of the encircling of the anulus of Zinn. The intraconal abducent nerve runs laterally to reach the lateral rectus muscle (Fig. 5).

The blood supply of the abducent nerve is well known. The cisternal segment is vascularized by the anterolateral arteries in 85.71%, by the AICA in 14.29%, and by pontomedullary artery in 7.14% of the cases. The intravenous portion is supplied by the posterior meningeal branch of the meningohypophyseal trunk. The intracavernous, intrafissural, and orbital segments receive their blood supply from the ophthalmic branch of the inferolateral trunk, the artery of the inferior cavernous sinus. The internal auditory artery and the pontomedullary artery cross the anterior surface of the cisternal segment, whereas the inferolateral pontine artery traverses the posterior surface. The anterolateral arteries may cross both the anterior and posterior surfaces.
Based on the classification proposed by Nathan, et al., we found two cases (25%) in which the anatomical course of the nerve could be classified as Pattern 3. Indeed, in one of the two cases the two trunks formed a relationship with a duplicated AICA, which crossed the nerves on the anterior surface; a branch of the AICA passed between the two nerve trunks. This close relationship between nerve and vessel may have a practical implication. Indeed, vascular malformations such as arteriovenous malformations, in which the AICA is the feeding vessel, or aneurysms involving the AICA could compress the nerve, inducing palsy and/or hyperactivity of the nerve.

There could be an embryological explanation for the duplication of the abducent nerve. Indeed, two aberrant roots of the abducent nerve have been consistently found in chicken and human embryos. The failure of these nerve roots to resolve in the adult life could form the basis of this anomaly.

In its venous segment the abducent nerve is situated just below and medial to the so-called petrous tubercle. This relationship has a great surgery-related relevance: this bone spur, where the Gruber ligament inserts, is an optimal intraoperative landmark by which to preserve the abducent nerve while performing a subtemporal-transentorial-transpetrous apex approach for the excision of posterior and middle fossa lesions. Drilling of the petrous apex, corresponding to the floor of the cavity of Meckel, should stop when this spur becomes visible in the operative field. Indeed, the petrous tubercle is 1.95 ± 0.75 mm from the nerve on the right side and 1.67 ± 1.02 mm on the left side.

The abducent nerve’s variations may have some practical surgery-related implications. The finding of this anomaly could explain some partial lesion of the nerve in which palsy of the lateral rectus muscle is present; perhaps, in these cases only, one of the two branches is affected by pathological processes or is damaged during the surgical procedures. While performing a surgical approach in the petroclival region, the surgeon should consider the possibility of an existing duplicated abducent nerve to avoid causing even partial postoperative deficits. Well-detailed magnetic resonance imaging studies, such as those with three-dimensional time-of-flight and fast-imaging steady-state precision sequences, can be very helpful in detecting this anatomical variation. The early intraoperative identification of single or duplicated abducent nerve, together with the recognition of surgical landmarks, such as the petrous tubercle, could reduce surgery-related risks and complications.

Conclusions

Duplication of the abducent nerve is a rare finding. The presence of this anatomical variation should be preoperatively identified using MR imaging to avoid causing even partial damage of the nerve during surgical procedures. Partial dysfunction of the abducent nerve encased by huge petroclival tumors could be explained by the existence of a second nerve root.

References


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