FOLIA MEDICA CRACOVIENSIA
Vol. LIX, 4, 2019: 13–20
PL ISSN 0015-5616
DOI: 10.24425/fmc.2019.131376

Bilateral duplication of the abducens nerve — case study

Robert Haładaj[1], Janusz Skrzat[2]

[1]Department of Normal and Clinical Anatomy, Chair of Anatomy and Histology, Medical University of Lodz
Łódź, Poland
[2]Department of Anatomy, Jagiellonian University Medical College, Kraków, Poland

Corresponding author: Janusz Skrzat, Ass. Prof.
Department of Anatomy, Jagiellonian University Medical College
ul. Kopernika 12, 31-034 Kraków, Poland
Phone/Fax: +48 12 422 95 11; E-mail: j.skrzat@uj.edu.pl

Abstract: The abducens nerve is characterized by a long intracranial course and complex topographical relationships. Anatomical knowledge may help to understand both the etiology and clinical symptoms of abducens nerve palsy. Typically, the single trunk of the abducens nerve travels on both sides. However, occasionally different variants of unilateral or bilateral duplications of the abducens nerve may be observed. The presented paper is a detailed anatomical description of bilateral duplication of the abducens nerve, with atypical appearance of the nerve in the cavernous sinus and normal distribution within the lateral rectus muscle on both sides of one cadaver. On the right side both trunks of the abducens nerve fused within the subarachnoid space and pierced the dura mater together. On the left side both trunks of the duplicated abducens nerve pierced the dura mater separately, entered the petrous apex separately and fused just below the petrosphenoidal ligament. Within the cavernous sinus the nerve divided once again into two filaments, which reunited into one trunk after crossing the horizontal segment of the intracavernous part of internal carotid artery. The orbital segments of the abducens nerve showed a typical course on both sides. Duplication of the abducens nerve is anatomical variation which should be taken into account during diagnostic and surgical procedures performed within the petroclival region and cavernous sinus.

Key words: anatomical variation, abducens nerve, Dorello's canal, petrosphenoidal ligament.

Introduction

The abducens nerve is characterized by long intracranial course and complex anatomical relationships. Based on topographical landmarks, five segments of this nerve may be distinguished: cisternal, petroclival and intracavernous segments are intracranial, while fissural and intraconal segments are classified as orbital [1, 2]. Each segment may be affected by numerous specific diseases which causes that diagnosis of abducens nerve's palsy may be difficult [1, 3, 4]. Thus, anatomical knowledge may help to understand both the etiology and clinical symptoms of abducens nerve damage. In particular, knowledge of variations of anatomical structures located within the petroclival region plays an important role due to dynamic development of modern diagnostic and neurosurgical procedures [5–8].

Typically, single trunk of the abducens nerve travels on both sides [1, 7, 9, 10]. The nerve emerges from the brainstem, runs within the subarachnoid space, pierces the dura mater to enter the Dorello's canal (the space between the posteromedial portion of the petrous apex and the petrosphenoidal ligament) and the cavernous sinus, and after reaching the orbit it terminates within the lateral rectus muscle [1–3, 9, 10]. However, occasionally different variants of unilateral or bilateral duplication of the abducens nerve may be observed [1–3, 7–10].

The presented paper is a detailed anatomical description of the bilateral duplication of the abducens nerve, with an atypical appearance of the nerve in the cavernous sinus and a normal distribution within the lateral rectus muscle on both sides. The clinical and diagnostic significance of the observed variations were also analyzed.

Materials and Methods

62-year-old male cadaver fixed in 10% formalin solution was routinely dissected for scientific and teaching purposes. Prior to opening the skull, initial head and neck examinations were performed, to exclude scars from injuries or surgeries. No macroscopic damages and pathologies were observed during the dissection.

In order to thoroughly examine the cranial nerves, the skull was opened using expanded access with removal of the occipital squama [10, 11]. The orbit was dissected according to the previously described protocol, through removal of the superior and lateral wall [12–14]. The distribution and course of individual cranial nerves in their intracranial segments (excluding abducens nerve) was typical. Due to the bilateral duplication of the abducens nerve, a detailed examination of the nerve was performed on its entire course. The procedure was performed with microsurgical instruments and a magnified vision of ×2.5 using a HEINE® HR 2.5 X High Resolution Binocular Loupe (HEINE Optotechnik GmbH & Co. KG, Herrsching, Germany). The

specimen was photographed with a scalebar and ImageJ software was used to take all measurements.

Case description

Cisternal segment of the abducens nerve was duplicated on both sides, including the origin from the pontomedullary sulcus (Fig. 1). On the right side both trunks: thinner (of 0.35 mm diameter) and thicker (of 0.84 mm diameter) fused within the subarachnoid space and pierced the dura mater together (Fig. 1). Within the petrous apex, a single abducens nerve's trunk (of 0.98 mm diameter) ran under the petrosphenoidal ligament. In the cavernous sinus, the nerve spilt into two separate filaments once again (the diameter of upper filament was 0.43 mm, while the diameter of the lower filament was 0.48 mm). The distance at which both filaments ran separately was 8.6 mm. Both filaments crossed the vertical segment of the cavernous internal carotid artery and reunited into single trunk (Fig. 2). The abducens nerve joined the orbit in a typical manner on this site. The single abducens nerve passed through the superior orbital fissure and common tendinous ring to innervate the lateral rectus muscle.

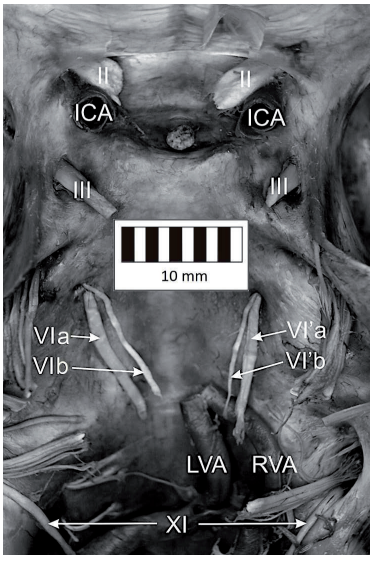

Fig. 1. Superior view to the posterior and middle cranial fossa. Bilateral duplication of the cisternal segment of the abducens nerve (VI) is exposed. On the right side, both trunks of duplicated abducens nerve: thicker (VI'a) and thinner (VI'b) pierce the dura mater together. On the left side, the two trunks of duplicated abducens nerve: thicker (VIa) and thinner (VIb) pierce the dura mater separately. (II) optic nerve; (III) oculomotor nerve; (XI) accessory nerve; (ICA) internal carotid artery; (LVA) left vertebral artery; (RVA) right vertebral artery.

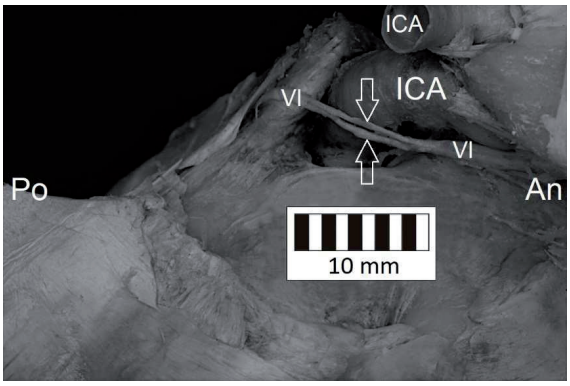

Fig. 2. Lateral view to the right cavernous sinus. In the cavernous sinus, the abducens nerve (VI) is divided (anatomical variation) into two separate filaments (marked by arrows) which cross vertical segment of the cavernous internal carotid artery (ICA) and then reunite into single trunk. (An) anterior; (Po) posterior.

On the left side, both trunks of the duplicated abducens nerve (thinner of 0.41 mm diameter and thicker of 1.02 mm diameter) pierced the dura mater separately (Fig. 1) and entered the Dorello's canal separately. Careful removal of the clival dura exposed the petrosphenoidal ligament. Both trunks fused just below the ligament and in the cavernous sinus continued as a single trunk of 1.18 mm diameter. However, at the level of the vertical segment of the internal carotid artery, the abducens nerve split into two filaments (the diameter of upper filament was 0.75 mm, while the diameter of the lower filament was 0.51 mm, Fig. 3). Both filaments reunited after short (7.2 mm) separate course (Fig. 3). Then, the abducens nerve entered the orbit in the typical manner to innervate the lateral rectus muscle.

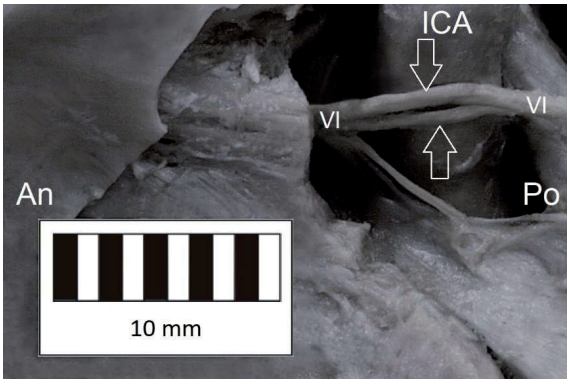

Fig. 3. Lateral view to the left cavernous sinus. Also on this side, intracavernous segment of the abducens nerve (VI) is divided into two separate filaments (marked by arrows) which cross vertical segment of the cavernous internal carotid artery (ICA) and then reunite into single trunk. (An) anterior; (Po) posterior.

The orbital segments of the abducens nerve showed a typical course on both sides, innervating only the lateral rectus muscle. The lateral rectus muscle was typical on both sides. Before entering the rectus lateral muscle, the abducens nerve divided into muscular sub-branches (Fig. 4).

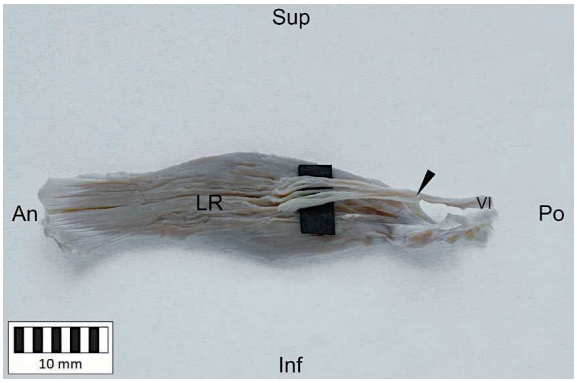

Fig. 4. Isolated lateral rectus muscle (LR) with orbital segment of the abducens nerve taken from the right orbit of the specimen described in this case report. Normal appearance of the lateral rectus and abducens nerve. View of the internal surface of the lateral rectus muscle. The division of the abducens nerve into muscular sub-branches to the lateral rectus muscle (black arrowhead) is seen. (An) anterior; (Po) posterior; (Sup) superior; (Inf) inferior; (VI) abducens nerve.

Discussion

Although the abducens nerve in humans supplies only the lateral rectus muscle, it is the structure of great functional and clinical significance. The abducens nerve is vulnerable to injury due to its long intracranial course [3, 13, 15]. Paralysis of this nerve may be caused, among others, by pathological lesions within the pons, pathologies within the subarachnoid space (especially associated with compression of the nerve against the clivus), as well as disease processes occurring in within the petrous apex (for example Gradenigo syndrome) [3, 15, 16]. Relationships to the internal carotid artery in the cavernous sinus are also significant, since the aneurysm of the internal carotid artery may cause compression of the nerve [15, 17, 18]. Paralysis of the abducens nerve may also be associated with medical procedures, such as skull base surgery [1–3, 7, 9]. In cases of duplication of the abducens nerve, the second trunk of the nerve may be accidentally damaged during those procedures. Abducens nerve palsy results in the limitation of abduction of the eye on the affected side, which causes the eye is directed medially (medial strabismus) because of unopposed tonus of the medial rectus muscle [15, 16]. The condition is commonly unilateral but can also occur bilaterally. Impaired abduction of the eye causes, especially in adults, double vision (horizontal diplopia) [15, 16].

The classical anatomical description refers to cases where the abducens nerve occurs throughout its course as a single trunk [1, 2, 7, 10, 19, 20]. This type was noted by Nathan *et al.* in 86.5% of cases [19]. Different variants of abducens nerve duplication were described. Nathan *et al.* and Ozveren *et al.* [19, 20] distinguished several types such as anatomic variation, including: single trunk leaving the brainstem and duplicated in the subarachnoid space into two trunks that reunite within the cavernous sinus; two trunks separately leaving the brainstem, joining within cavernous sinus; two trunks over the entire course from the brainstem to the superior orbital fissure. Report on the duplication of the abducens nerve throughout the entire course was presented by Jain [21]. A case of abducens nerve duplication limited to the sphenopetroclival venous gulf and the cavernous sinus was described by Coquet *et al.* [22]. Kshettry [9], on the basis of data from the literature, estimated the incidence of duplication of abducens nerve at 7.6% (35 of a total 462 analyzed cases). Duplication of the abducens nerve seems not affect the function of the lateral rectus muscle. There are reports in the literature of the correct abduction of the eye in patients with abducens nerve duplication observed in MRI [8, 23].

As a separate variation are classified cases in which abducens nerve branches into numerous filaments over a short distance in the cavernous sinus. This type has been described by Harris and Rhotton [24], Ozer *et al.* [25], as well as by Joo *et al.* [26]. Harris and Rhotton [24] reported that abducens nerve may occasionally split into two to five filaments in the cavernous sinus. In the research of Ozer *et al.* [25] the frequency of branching of the cavernous segment of the abducens nerve over a limited distance was estimated at 37.5% (20% double branching, 17.5% triple branching). Joo *et al.* [26] noted abducens nerve branching in the lumen of cavernous in 35% of cases (involving double or triple branching). In the presented work, abducens nerve branching in the cavernous sinus into two filaments occurred bilaterally and coexisted with duplication of the abducens nerve in the subarachnoid space (on the right side) or in the subarachnoid space and petrous apex (on the left side).

Typically, in the posteromedial portion of the petrous apex, the abducens nerve runs under the petrosphenoidal ligament, within the space known as the Dorello's canal [1, 2, 7, 9–11, 19, 20]. Such course was observed bilaterally in this study. However, in the cases of duplication of abducens nerve, in which two independent trunks of this nerve occur within the petrous apex, also an unusual course of one of the trunks may be observed, above the petrosphenoidal ligament [1, 2, 7, 9, 10, 19, 20]. In the study of Nathan *et al.* [19], in each of the 9 cases of abducens nerve duplication noted by this author, one trunk coursed below and the other above the petrosphenoidal ligament. In research conducted by Ozveren *et al.* [20], out of 15 cases of abducens nerve's duplication, only in two cases the course of one of the trunks above petrosphenoidal ligament was observed. In contrast, in the study of Wysiadecki *et al.* [10], an unusual course of one of the trunks of the abducens nerve above the ligament was observed

in 3 out of 4 cases of abducens nerve duplication (75% of cases of abducens nerve duplication). In one remaining case from those series, the two trunks reunited below the petrosphenoidal ligament, as in the left side of specimen described in presented report. Relation of the abducens nerve to the petrosphenoidal ligament may be of practical value. The petrosphenoidal ligament protects abducens nerve when it runs below. This relation is of great practical importance during drilling the petrous bone [26, 27]. Demonstrating anatomical variants of structures located in various regions of the skull base, may be crucial from the didactic and practical point of view [7, 26–29].

Conclusions

Duplication of the abducens nerve may occur in numerous types. It is anatomical variation which should be taken into account during diagnostic and surgical procedures performed within the petroclival region and cavernous sinus.

Conflict of interest

None declared.

References

1. *Iaconetta G., Fusco M., Cavallo L.M., Cappabianca P., Samii M., Tschabitscher M.*: The abducens nerve: microanatomic and endoscopic study. Neurosurgery. 2007; 61 (3 Suppl.): 7–14.
2. *Zhang Y., Yu H., Shen B.Y., Zhong C.J., Liu E.Z., Lin Y.Z., Jing G.H.*: Microsurgical anatomy of the abducens nerve. Surg Radiol Anat. 2012; 34 (1): 3–14.
3. *Baidoo E.A., Tubbs R.S.*: Anatomy of the abducens nerve. In Nerves and nerve injuries. Vol. 1: History, embryology, anatomy, imaging, and diagnostics, Eds. Tubbs R.S., Rizk E., Shoja M., Loukas M., Spinner R.J., Barbaro N. 1st edition; London: Elsevier 2015; 351–356.
4. *Elder C., Hainline C., Galetta S.L., Balcer L.J., Rucker J.C.*: Isolated Abducens Nerve Palsy: Update on Evaluation and Diagnosis. Curr Neurol Neurosci Rep. 2016; 16 (8): 69.
5. *Li C., Tang Y., Ge H., Lin X., Sun B., Feng L., Liu S., Liu C., Liang C., Zhang Z., Liu S.*: Sectional anatomy of the abducens nerve: according to 3D-SPACE magnetic resonance sequences correlated with cryosectional specimens. Surg Radiol Anat. 2015; 37 (8): 921–929.
6. *Özgür A., Esen K., Kara E., Temel G.O.*: Visualization of the Abducens Nerve in its Petroclival Segment Using Contrast-Enhanced FIESTA MRI: The Size of the Petroclival Venous Confluence Affects Detectability. Clin Neuroradiol. 2017; 27 (1): 97–103.
7. *Wang J.M.H., Edwards B.A., Loukas M., Oskouian R.J., Tubbs R.S.*: Supernumerary Abducens Nerves: A Comprehensive Review. World Neurosurg. 2018; 112: 39–45.
8. *Yamashiro T., Yonahara M., Yonaha A., Kinoshita R., Tsubakimoto M., Iraha R., Murayama S.*: Bilateral duplication of the abducens nerves: an incidental finding on magnetic resonance imaging. Jpn J Radiol. 2015; 33 (12): 772–775.
9. *Kshettry V.R., Lee J.H., Ammirati M.*: The Dorello canal: historical development, controversies in microsurgical anatomy, and clinical implications. Neurosurg Focus. 34 (3): E4. doi: 10.3171/2012.11.FOCUS12344.

10. *Wysiadecki G., Orkisz S., Gałązkiewicz-Stolarczyk M., Brzeziński P., Polguj M., Topol M.*: The abducens nerve: its topography and anatomical variations in intracranial course with clinical commentary. Folia Morphol (Warsz). 2015; 74 (2): 236–244.
11. *Wysiadecki G., Haładaj R., Polguj M., Żytkowski A., Topol M.*: Bilateral Extensive Ossification of the Posterior Petroclinoid Ligament: An Anatomical Case Report and Literature Review. J Neurol Surg A Cent Eur Neurosurg. 2019; 80 (2): 122–126.
12. *Haładaj R., Wysiadecki G., Polguj M., Topol M.*: Bilateral muscular slips between superior and inferior rectus muscles: case report with discussion on classification of accessory rectus muscles within the orbit. Surg Radiol Anat. 2018; 40 (7): 855–862.
13. *Haładaj R., Polguj M., Topol M.*: Anatomical Variations of the Supraorbital and Supratrochlear Nerves: Their Intraorbital Course and Relation to the Supraorbital Margin. Med Sci Monit. 2019; 25: 5201–5210.
14. *Haładaj R., Wysiadecki G., Tubbs R.S.*: Intramuscular innervation of the lateral rectus muscle evaluated using sihler's staining technique: Potential application to strabismus surgery. Clin Anat. 2019. doi: 10.1002/ca.23452.
15. *Azarmina M., Azarmina H.*: The six syndromes of the sixth cranial nerve. J Ophthalmic Vis Res. 2013; 8 (2): 160–171.
16. *Wilson-Pauwels L., Stewart P.A., Akesson E.J., Spacey S.D.*: Cranial Nerves: Function & Dysfunction. Shelton, Connecticut: People's Medical Publishing House-USA, 3rd edition 2013; 112–118.
17. *Jittapiromsak P., Sabuncuoglu H., Deshmukh P., McDougall C.G., Spetzler R.F., Preul M.*: Anatomical relationships of intracavernous internal carotid artery to intracavernous neural structures. Skull Base. 2010; 20 (5): 327–336.
18. *Kashiwazaki D., Kuwayama N., Akioka N., Kuroda S.*: Delayed abducens nerve palsy after transvenous coil embolization for cavernous sinus dural arteriovenous fistulae. Acta Neurochir. 2014; 156 (1): 97–101.
19. *Nathan H., Ouaknine G., Kosary I.Ż.*: The abducens nerve. Anatomical variations in its course. J Neurosurg. 1974; 41 (5): 561–566.
20. *Ozveren M.F., Sam B., Akdemir I., Alkan A., Tekdemir I., Deda H.*: Duplication of the abducens nerve at the petroclival region: an anatomic study. Neurosurgery. 2003; 52 (3): 645–652.
21. *Jain K.K.*: Aberrant roots of the abducens nerve. J Neurosurg. 1964; 21: 349–351.
22. *Coquet T., Lefranc M., Chenin L., Foulon P., Havet É., Peltier J.*: Unilateral duplicated abducens nerve coursing through both the sphenopetroclival venous gulf and cavernous sinus: a case report. Surg Radiol Anat. 2018; 40 (7): 835–840.
23. *Kim J.H., Hwang J.M.*: Normal abduction in a patient with duplicated abducens nerve. Korean J Ophthalmol. 2005; 19 (4): 305–306.
24. *Harris F.S., Rhoton A.L.*: Anatomy of the cavernous sinus. A microsurgical study. J Neurosurg. 1976; 45 (2): 169–180.
25. *Ozer E., Icke C., Arda N.*: Microanatomical study of the intracranial abducens nerve: clinical interest and surgical perspective. Turk Neurosurg. 2010; 20 (4): 449–456.
26. *Joo W., Yoshioka F., Funaki T., Rhoton A.L. Jr.*: Microsurgical anatomy of the abducens nerve. Clin Anat. 2012; 25 (8): 1030–1042.
27. *Ozveren M.F., Uchida K., Aiso S., Kawase T.*: Meningovenous structures of the petroclival region: clinical importance for surgery and intravascular surgery. Neurosurgery. 2002; 50 (4): 829–836.
28. *Skrzat J., Mróz I., Spulber A., Zarzecki M., Walocha J.*: Ossification of the petrosphenoid ligament — a case study. Folia Med Cracov. 2017; 57 (2): 87–94.
29. *Skrzat J., Bonczar A., Kasprzycki T.*: Printable 3D model of the sella turcica region including the interclinoid bridge. Folia Med Cracov. 2018; 58 (4): 5–12.