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The cisternal segment of the abducens nerve in man: three-dimensional MR imaging

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Abstract

Purpose: The goal of this study was to identify the abducens nerve in its cisternal segment by using three-dimensional turbo spin echo T2-weighted image (3DT2-TSE). The abducens nerve may arise from the medullopontine sulcus by one singular or two separated rootlets. *Material and methods:* We studied 285 patients (150 males, 135 females, age range: 9–72 years, mean age: 33.3 ± 14.4) referred to MR imaging of the inner ear, internal auditory canal and brainstem. All 3D T2-TSE studies were performed with a 1.5 T MR system. Imaging parameters used for 3DT2-TSE sequence were TR:4000, TE:150, and 0.70 mm slice thickness. A field of view of 160 mm and 256 × 256 matrix were used. The double rootlets of the abducens nerve and contralateral abducens nerves and their relationships with anatomical structures were searched in the subarachnoid space. *Results:* We identified 540 of 570 abducens nerves (94.7%) in its complete cisternal course with certainty. Seventy-two cases (25.2%) in the present study had double rootlets of the abducens nerve. In 59 of these cases (34 on the right side and 25 on the left) presented with unilateral double rootlets of the abducens. Thirteen cases presented with bilateral double rootlets of the abducens (4.5%). *Conclusion:* An abducens nerve arising by two separate rootlets is not a rare variation. The detection of this anatomical variation by preoperative MR imaging is important to avoid partial damage of the nerve during surgical procedures. The 3DT2-TSE as a noninvasive technique makes it possible to obtain extremely high-quality images of microstructures as cranial nerves and surrounding vessels in the cerebellopontine cistern. Therefore, preoperative MR imaging should be performed to detect anatomical variations of abducens nerve and to reduce the chance of operative injuries.

Keywords: Abducens nerve; Double rootlets; Magnetic resonance imaging

1. Introduction

The abducens nerve has the longest course along the skull base and usually exits the brainstem as a single trunk. [1–3]. However, in about 13% of human individuals, the nerve may arise by two separate radices which, in turn, join together either in the epidural space or the cavernous sinus [3,4]. In rare cases, both rootlets of the abducens nerve remain separated until they reach their target in orbit, i.e. the lateral rectus muscle [2].

Magnetic resonance imaging techniques have significant contribution to knowledge of neuroanatomy. It is a noninvasive and easily evaluated sequence to reveal the nervous system anatomy and its variations beside the dissection of cadaver. Recent advances in the field of imaging techniques, cranial base surgery, and endovascular interventions have enabled surgeons to make interventions upon the cavernous sinus. The thin-slice three-dimensional turbo spin echo T2 (3DT2-TSE) MR imaging technique allows an easy and accurate evaluation of the course of the nerves in subarachnoid space [5]. To know the exact anatomy before the operation is crucial and can be achieved with the aforementioned MR imaging sequence. In the present study, the variation as double abducens nerve during MR imaging and the practical importance of this finding were evaluated.

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2. Material and methods

We studied 285 patients (150 males, 135 females, age range: 9–72 years, mean age: 33.3 ± 14.4) referred to MR imaging of the inner ear, internal auditory canal and brainstem. All 3DT2-TSE studies were performed with a 1.5 T MR system (Philips Gyroscan, Intera Master, Best, The Netherlands). Imaging parameters used for 3DT2-TSE sequence were TR: 4000, TE: 150, and 0.70 mm slice thickness. A field of view of 160 mm and 256 × 256 matrix were used. The time required for this sequence was approximately 2.30 min. Patients showing lesions in the brainstem region were excluded. No abducens nerve palsy was present in any of the subjects. All examinations were retrieved from digital archive and viewed on an independent workstation, without magnification. The images were analyzed by two independent observers (AA, AS). As part of the bilateral evaluation of the abducens nerve in 285 individuals, several anthropometric data were collected. We measured:

(a) if present, the distance between the individual rootlets of each abducens;
(b) the distance between the medial edges of the rootlets of both abducens nerve;
(c) the antero-posterior extension of the subarachnoid portion of the abducens nerve (i.e. the distance between its origin in the medullopontine sulcus and the point where it pierce the dura mater);
(d) the distance between the abducens nerve where it pierces the dura matter and the internal acoustic meatus;
(e) if present, the length of the evagination of the arachnoid membrane into the epidural canal for the abducens nerve.

Evagination of the arachnoid membrane into the narrow canal for the abducens nerve within the epidural space has been classified as follows: 0 mm (no evagination), less than 1, 1–2 mm, or more than 2 mm.

All statistical analyses were performed using a commercially available SPSS release 10.0 software package (SPSS Inc., Chicago, IL). The results are presented as mean ± standard deviation in order to facilitate comprehension of the tables. One sample Kolmogorov–Smirnov test demonstrated normal distribution of measurements of abducens nerves in subjects. Student's *t*-test was used for the assessment of whether there is a difference in the measurements of between double rootlets of the abducens nerve side and contralateral side.

3. Results

Five hundred and seventy abducens nerves in 285 patients were examined using the 3DT2-TSE sequence.

We identified 540 of 570 abducens nerves (94.7%) in its complete cisternal course with certainty.

Seventy-two cases (25.2%) in the present study had double rootlets of the abducens nerve. In 59 cases of 72 presented with unilateral double rootlets of the abducens. Thirty-four cases had right (11.9%) and 25 cases (8.7%) had left double rootlets. 13 cases presented with bilateral double rootlets of the abducens (4.5%).

The anthropometric data was presented in Table 1.

Evidence of the evagination of the arachnoid membrane was detected in the epidural part of the abducens nerve in 91.6% of double rootlets and in 85.9% of the contralateral abducens nerves. The length of the evagination both for double rootlets and contralateral abducens nerves was in 27.7% and in 20.3% of nerves for less than 1 mm, in 31.9% and in 51.5% of nerves for between 1 and 2 mm, and in 40.2 and 28.1% of nerves for longer than 2 mm, respectively. Comparison of the measurements between the double rootlets of the abducens nerve and contralateral site revealed no statistical significance ($P > 0.05$).

4. Discussion

The abducens nerve fibers originate from a nucleus in the floor of the fourth ventricle. The nerve emerges just above the pyramids from the medullopontine sulcus on the anterior aspect of the brainstem, after which it runs upwards, forwards and laterally in the pontine cistern (Fig. 1A). It pierces the dura mater inferolaterally to the dorsum sellae along its dural sleeve in the petroclival venous confluence (Fig. 1B). It then runs in a sulcus close to the petrous apex, to continue through the cavernous sinus lateral to the internal carotid artery. It passes through the superior orbital fissure and the common tendinous ring from which the rectus muscles arise. It ends at the medial surface of the lateral rectus muscle [6,7]. The bony canal (Dorello's canal) which is

Table 1
The anthropometric data of measurements related with double rootlets and contralateral side of the abducens nerve

	Abducens nerve (mm)				
	A	*B*	*C*	*D*	*E*
Double rootlets of the abducens nerve	2.6 ± 0.4	17.5 ± 1.8	6 ± 1.2	14.8 ± 1.7	1.7 ± 0.7
Contralateral abducens nerve	–	–	5.9 ± 1.2	15.2 ± 1.7	1.7 ± 0.6

A: The distance between the individual rootlets of each abducens; *B*: the distance between the medial edges of the rootlets of both abducens nerve; *C*: the antero-posterior extension of the subarachnoid portion of the abducens nerve; *D*: the distance between the abducens nerve where it pierces the dura matter and the internal acoustic meatus; *E*: the length of the evagination of the arachnoid membrane into the epidural canal for the abducens nerve.

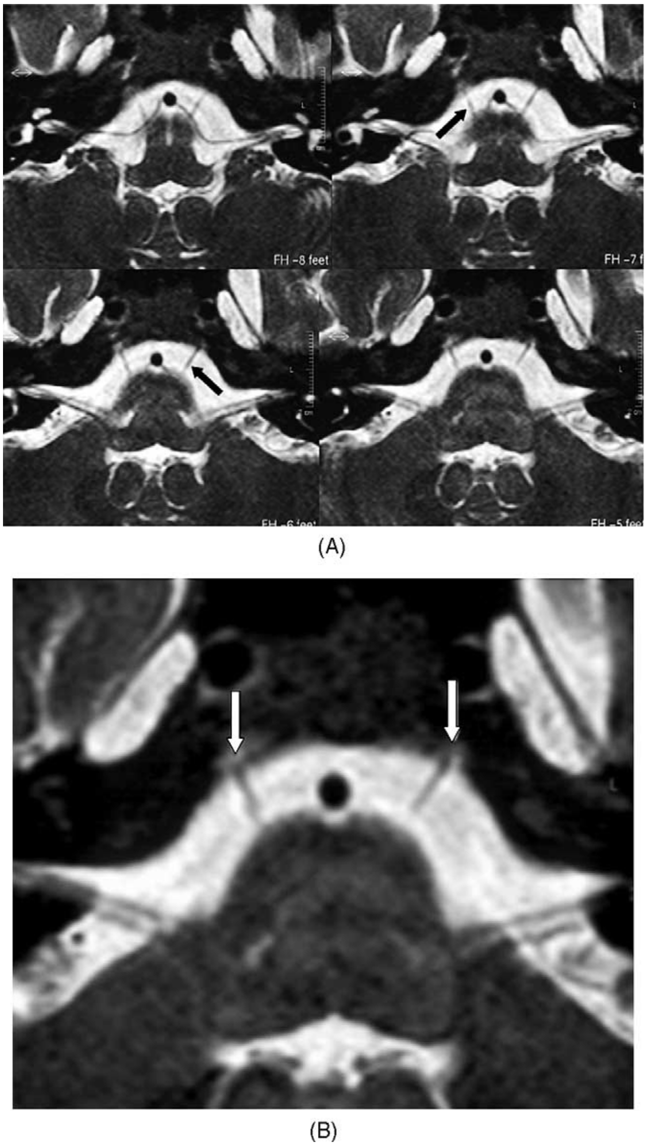

Fig. 1. MR images obtained in the axial plane by using a 3DT2-TSE sequence. (A) Serial axial 3DT2-TSE images at the level of cisternal segment of the abducens nerve (arrows) shows the entire nerve between the brainstem and epidural part of the abducens nerve. (B) Epidural part of the abducens nerve (arrows) can be identified as a CSF filled evagination.

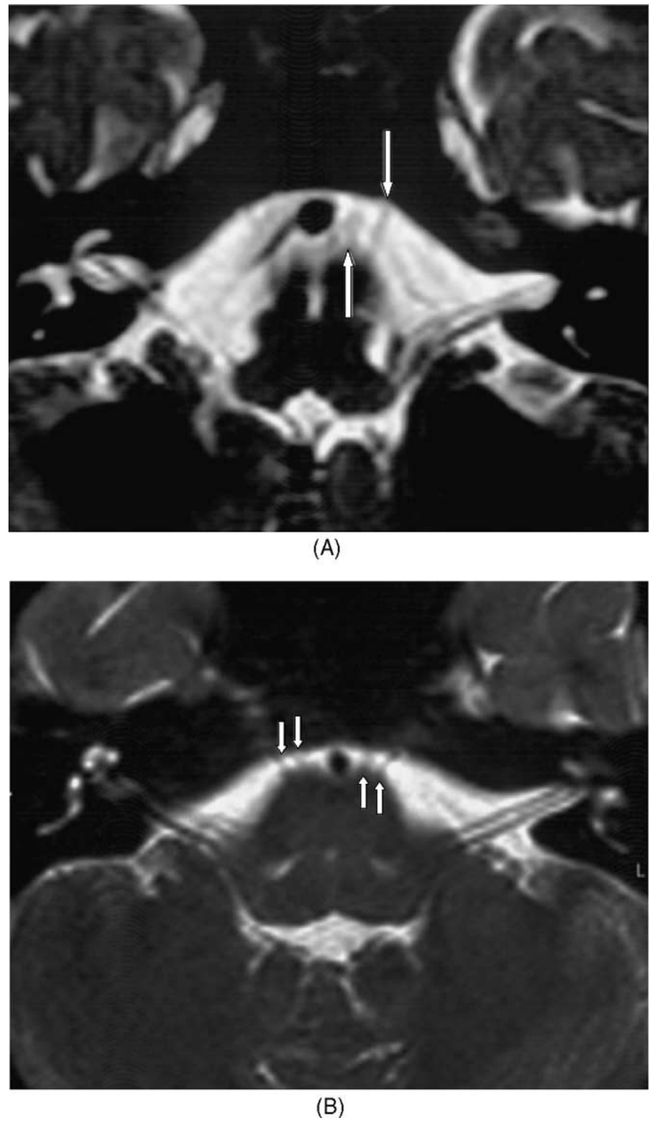

Fig. 2. Axial 0.7 mm 3DT2-TSE images show (A) double rootlets of the abducens nerve on the left side (arrows) and (B) double rootlets of the abducens nerve on both sides (arrows).

sometimes found at the tip of the temporal bone enclosing the abducens nerve and inferior petrosal sinus as these two structures enter the cavernous sinus [1,8–13].

Well-detailed studies on the anatomical variations of cranial nerves have been performed after improvements of microsurgical procedures in petroclival and cavernous sinus surgery [1]. Ozveren et al. [14] explained the incidence of duplication and of bilaterally double rootlets of the abducens nerve as 15 and 8%, respectively. The incidence of double rootlets of the abducens nerve in the present study was 59 cases (20.7%) unilaterally (34 cases on the right (11.9%) and 25 cases (8.7%) on the left) and 13 cases (4.5%) bilaterally (Fig. 2A and B). The anthropometric data of our study was not revealed any significant intraindividual variability for measurements between the double rootlets of the abducens nerve and contralateral site (Table 1). In the cisternal segment, two (28.5–40% of cases) or three nerve trunks (10.7% of cases) have been found in the literature [10,11,13]. Dural hole is usually single (93–95%) and contains one (45–94%) or two nerve trunks (55%). Duplication of the dural foramen, with each hole containing a single trunk, has also been described (5–13.5%) [2,3,15]. Bremer [16] revealed that the existence of two (or theoretically even more) separate radices forming the abducens nerve is mainly due to the rostrocaudal arrangement of its nucleus. Thus, the neurons within that nucleus may be arranged in two distinct groups in rostrocaudal sequence which, in turn, may form two separate rootlets. These rootlets may unite either within the brainstem in those cases presenting a singular stemmed abducens nerve or within the subarachnoid or even epidural space. Furthermore, according to the rostrocaudal orientation of the abducens nerve nucleus, it is also evident that rootlets will not emerge from the brainstem in the same horizontal plane.

The standard and reliable identification of the abducens nerve have been always difficult regularly during conventional MR imaging [8]. 3DT2-TSE sequence has become clinically available as a result of recent technological advances in MR imaging; in particular, the development of high-speed data processing, which makes it possible to obtain high-resolution images with an acceptable signal-to-noise (S/N) ratio by 3D data acquisition. The 3DT2-TSE sequence permits small peripheral branches of blood vessels to be displayed with high resolution, because the cerebral cisterns, nerves, and blood vessels are displayed with high contrast [5]. The abducens nerve can reliably be identified when using a 3DT2-TSE sequence. The search for the abducens nerve in the axial plane can be facilitated by starting with those slices on which the facial colliculus is identified [8]. The identification of epidural part of the abducens nerve is important to map the anatomical course of the structure suspected to be the nerve because of the very similar signal intensities of vessels within the subarachnoid space observed using this sequence are indistinguishable from those of nerves. This sequence is expected to take place of conventional preoperative evaluation techniques, since the courses of small nerves and blood vessels can be displayed on the same image [5]. In the literature, It was shown that every fascicle of abducens nerve entered their own separate pores in anatomical studies [14,17]. In the present study, MR imaging was not adequate to show the entrance of each fascicle to separate pores.

The abducens nerve variations may cause some practical surgery-related implications. In the presence of double rootlets of the abducens nerve, injury to one of the branches may be the cause of a temporary or permanent nerve paralysis [14]. During a surgical approach especially in the petroclival region, the surgeon should consider the possibility of existing double rootlets of the abducens nerve to avoid causing even partial postoperative deficits [1]. Presented data disclosed that evagination of the arachnoid membrane was at most 1–2 mm on the contralateral side while the value could be more than 2 mm on the duplicated side.

Abducens nerve is either adjacent to the petrous apex or close to the basilar plexus. Furthermore, in the individuals presenting with double radices of the abducens nerve, the caudal rootlet has to pass below the petrosphenoidal ligament [3]. During a transpetrosal approach for neoplasms of the cranial base extending toward the petroclival region, the mechanical trauma or heat dissipated from the drill may cause injury to the nerve [14]. Ozveren et al. [14] indicated that if one of the branches of the abducens nerve may pass over the petrosphenoidal ligament [10,14], this may be more prone to injury during surgery and may result in paralysis of the lateral rectus muscle. The aggressive surgical approaches to the clivus, petroclival region, and cavernous sinus require a better knowledge of the microanatomy of the neurovascular structures and variations in the course of the nerves especially the abducens nerve in those areas to prevent damage and resultant complications [14,15,17,18].

5. Conclusions

The imaging of double abducens nerve is not a rare variation. The detection of this anatomical variation by preoperative MR imaging is important to avoid partial damage of the nerve during surgical procedures. The 3DT2-TSE as a noninvasive technique makes it possible to obtain extremely high-quality images of microstructures as cranial nerves and surrounding vessels in the cerebellopontine cistern. Therefore, preoperative MR imaging should be performed to detect anatomical variations of abducens nerve and to reduce the chance of operative injuries.

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