AN ENDOSCOPE-ASSISTED CRANIOMETRIC CADAVERIC STUDY FOR THE BRAIN STEM AND THE CISTERNAL SEGMENT OF THE TROCHLEAR NERVE

Ahmet Tulgar BAŞAK[1], Nazlı ÇAKICI[2]

[1]Neurosurgery Department, VKV American Hospital, Nişantaşı, İstanbul, Turkey
[2]Neurosurgery Department, Medicana Internatıonal Hospital, Beylikdüzü, İstanbul, Turkey

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Background and purpose – This study analyzed the relationship of trochlear nerve with neurovascular structures using craniometric measurements. The study was aimed to understand the course of trochlear nerve and minimize the risk of injury during surgical procedures.
Methods – Twenty trochlear nerves of 10 fresh cadavers were studied bilaterally using endoscopic assistance through the view afforded by the lateral infratentorial-supracerebellar, and the combined presigmoid-subtemporal transtentorial approaches. Trochlear nerves were exposed bilaterally taking seven parameters into consideration: the distance between the cisternal segment of trochlear nerve and vascular structures (superior cerebellar artery/SCA; posterior cerebral artery/PCA), the origin of the trochlear nerve in the brain stem, the angle in the level of tentorial junction, length, diameter, and length of nerve in the cisternal segment.
Results – We identified the brain stem and cisternal segments of the trochlear nerve. The lateral infratentorial supracerebellar approach allowed the exposure of the cisternal segments (crural and ambient cisterns), including the origin of the nerve in the brain stem. The combined presigmoid-subtemporal transtentorial approaches provided visualization of the cisternal segment of the nerve and the free edge of the tentorium. In this study, the mean length and width of the trochlear nerve in the cisternal segment were 30.3 and 0.74 mm, respectively. Length of the trochlear nerve from its origin to its dural entrance was 37.2 mm, tentorial dural entrance angle of the trochlear nerve and exit angle of the trochlear nerve from the brain stem were 127.0 degrees and 54 degrees, PCA to trochlear nerve in mid ambient cistern and SCA to

A TROCHLEARIS IDEG AGYTÖRZSI ÉS CISTERNALIS SZEGMENSÉNEK ENDOSZKÓPASSZISZTÁLT CRANIOMETRICUS CADAVERVIZSGÁLATA
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Háttér és cél – Vizsgálatunk célja a trochlearis ideg és a neurovascularis struktúrák kapcsolatának feltárása volt craniometriás mérések segítségével. Célunk volt a trochlearis ideg lefutásának megértése és ezáltal az ideg sérülésének minimalizálása a sebészi beavatkozások során.
Módszerek – Tíz friss cadaver húsz trochlearis idegét tanulmányoztuk bilateralisan endoszkópos segítséggel, lateralis infratentorialis-supracerebellaris és kombinált praesigmoidalis-subtemporalis transtentorialis megközelítésekből. A trochlearis idegeket mindkét oldalon feltártuk, és megmértük a következő hét paraméterüket: a trochlearis ideg cisternalis szegmense és az érstruktúrák (arteria cerebellaris superior és arteria cerebellaris posterior) közötti távolság; a trochlearis ideg eredete az agytörzsben; a tentorialis junctio szintjén mért szög; hossz; átmérő; a trochlearis ideg hossza a cisternalis szegmensben.
Eredmények – Azonosítottuk az agytörzset és a trochlearis ideg cisternalis szegmensét. A lateralis infratentorialis-supracerebellaris megközelítés lehetővé tette a cisternalis szegmens (cruralis és ambiens cisternák) feltárását, ezen belül az ideg agytörzsi eredetének feltárását. A kombinált praesigmoidalis-subtemporalis transtentorialis megközelítés lehetővé tette az ideg cisternalis szegmensének és a tentorium szabad szélének vizualizálását. Mérésünk szerint a trochlearis ideg cisternalis szegmensének átlagos hossza és átmérője 30,3 és 0,74 mm volt. A trochlearis ideg hossza az eredetétől a durába lépéséig 37,2 mm volt. A trochlearis ideg tentorialis durába lépési szöge és az agytörzsből való kilépési szöge 127,0 fok, illetve 54 fok volt. A trochlearis ideg és az arteria cerebellaris posterior közötti távolság az ambiens cisterna közepén 7,3 mm volt.

Correspondent: Nazlı ÇAKICI MD, Medicana International Hospital;
Beylikdüzü Caddesi No:3, 34100, Beylikdüzü, İstanbul, Turkey.
Telephone number: +90 530575 9556. E-mail: drnazlicakici@yahoo.com
https//:orcid.org/0000-0003-1480-6235

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trochlear nerve in mid ambient cistern were 7.3 mm and 6.8mm.
Conclusion – Trochlear nerve is vulnerable to injury during the surgical procedures. Therefore, it is necessary to have a sufficient knowledge of the anatomy of cisternal segment and its relationship with adjacent neurovascular structures. The anatomical and craniometric data can be helpful in middle and posterior fossa surgery in minimizing the potential injury of the trochlear nerve.

Keywords: *anatomy, craniometry, Surgimap, trochlear nerve, trochlear nerve injury*

A trochlearis ideg és az arteria cerebellaris anterior közötti távolság az ambiens cisterna közepén 6,8 mm volt.
Következtetés – A trochlearis ideg gyakran megsérül a sebészeti beavatkozások során. Ezt megelőzendő, fontos cisternalis szegmense anatómiájának pontos ismerete és az ideg neurovascularis struktúrákkal való kapcsolatának feltárása. A trochlearis ideg sérülésének minimalizálása érdekében a középső és a hátulsó koponyaalap műtétei során hasznos az ideg anatómiai és craniometriás adatainak ismerete.

Kulcsszavak: *anatómia, craniometria, Surgimap, trochlearis ideg, trochlearisideg-sérülés*

The trochlear nerve is the cranial nerve with the longest intracranial course (approximately 60 mm), but also the thinnest (0.75–1 mm)[1]. The trochlear nerves arise from the inferolateral part of the inferior colliculus in the dorsal midbrain[2]. Nerve fibers decussate in the superior medullary velum and innervate contralateral superior oblique muscles. The superior oblique muscle rotates the eye inward and downward. The trochlear nerve is a somatic efferent nerve that courses in basal cisterns. After entering the tentorial incisura, it courses interdural[3]. This nerve has been described in literature with brain stem, cisternal, tentorial, cavernous, and orbital segments[2, 4–6]. Because of its thin structure and concealed location in the inferior part of the tentorium, it is very vulnerable to injury – especially the cisternal segment – during surgical procedures. In this study, we examined the angle of the nerve from the dorsal midbrain, its relationship with the other neurovascular structures in the ambient cistern, and its relation with the tentorial incisura. Endoscopic assistance and craniometric measurements used in this study were done based on the anatomical landmarks. We hope these measurements will assist surgeons in preoperative planning with the intraoperative anatomy-based navigation information and thereby minimize the risk of morbidity.

Materials and methods

In this study, we used ten fresh cadaveric heads. The cadavers were obtained from Medipol University Anatomy Department and the study was carried out in the Anatomy laboratory of Medipol University. Cadavers without any identified intracranial pathology were included in the study. Six of the cadavers were male, and four were female. The age of cadavers was varying between 52 and 85 years. The average age was 69.1 years.

In order to reveal the brain stem and the cisternal segments of the nerve, subtemporal and supracerebellar infratentorial approaches were performed with endoscopic assistance. The heads were positioned with a three-pin skull clamp (Doro QR3, USA) in vertical position. Initially, a standard supracerebellar infratentorial approach was used to expose the origin of both trochlear nerves at the midbrain. Tentorial leaves were lateralized by using 2.0 sutures. Retractors were placed in vertical position, and arachnoid adhesions were carefully dissected. Endoscopic assistance and measurements used to expose the cisternal segment of the nerve were done according to the identified landmarks. Later on, subtemporal approach was performed, and the temporal lobe was retracted carefully. The cisternal segment of the trochlear nerve was visualized in the ambient and crural cisterns. Anatomical position of the nerve was preserved as much as possible (in cadaveric specimens the positions of anatomical structures may be altered few millimeters after aspiration of the cerebrospinal fluid) and craniometric measurements were done using calipers **(Figures 1–6)**. The nerve was followed and visualized up to the free edge of the tentorium. Endoscopic procedures were performed by using rigid endoscopes (Karl Storz GmbH.Co, Tuttlingen, Germany) and 0, 30, and 45° lenses. Angle measurements were calibrated with Surgimap (New York, USA) software program.

Results

The following seven parameters were determined for nerve protection during surgery: 1. Distance

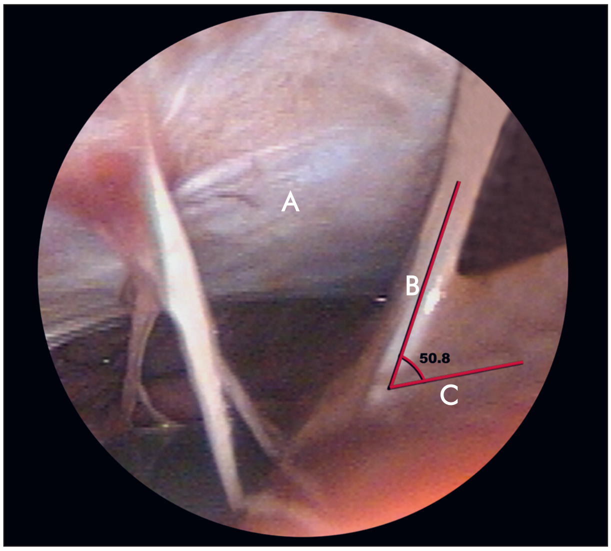

Figure 1. *The angle of exit of the 4th nerve from the brain stem (left side, infratentorial supracerebellar approach, 30° endoscopic view):* **A.** *tentorium,* **B**. *4th nerve,* **C.** *brain stem*

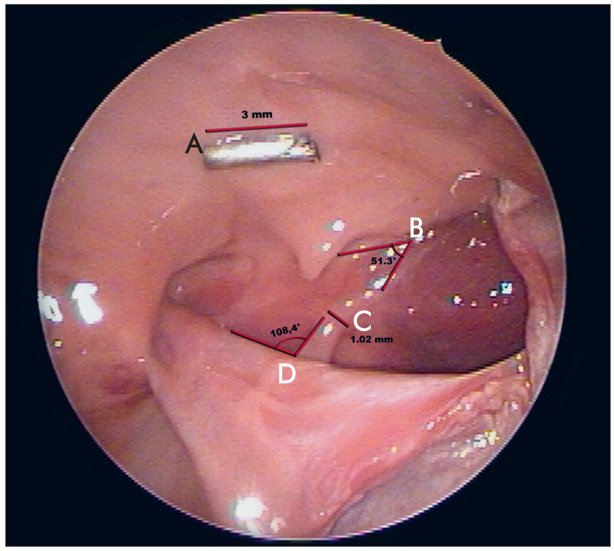

Figure 2. *The angle of exit of the 4th nerve from the brain stem, angle of participation in the tentorium and the thickness of the 4th nerve (left subtemporal approach, 0° endoscopic view):* **A**. *scale,* **B**. *angle of exit from the brain stem,* **C**. *the thickness of the nerve,* **D**. *participation angle in the tentorium*

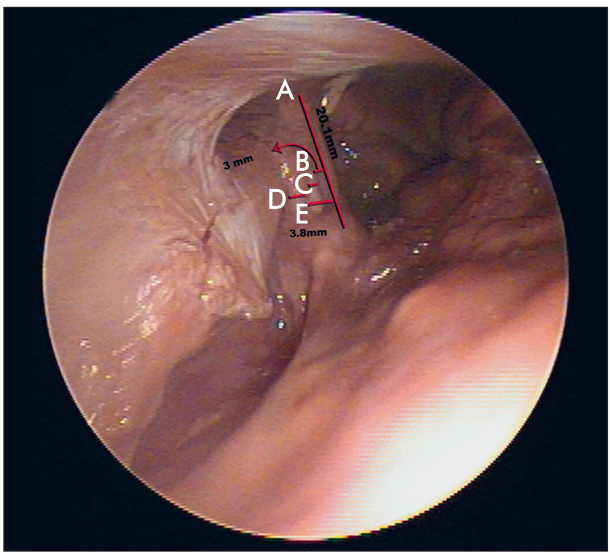

Figure 3. *The length of the 4th nerve in the cistern and its relationship with SCA, PCA (right subtemporal view with 45° endoscopic view):* **A.** *the length of the 4th nerve,* **B.** *the distance between the SCA and the 4th nerve,* **C.** *SCA,* **D**. *PCA,* **E.** *the distance between the 4th nerve and the PCA*

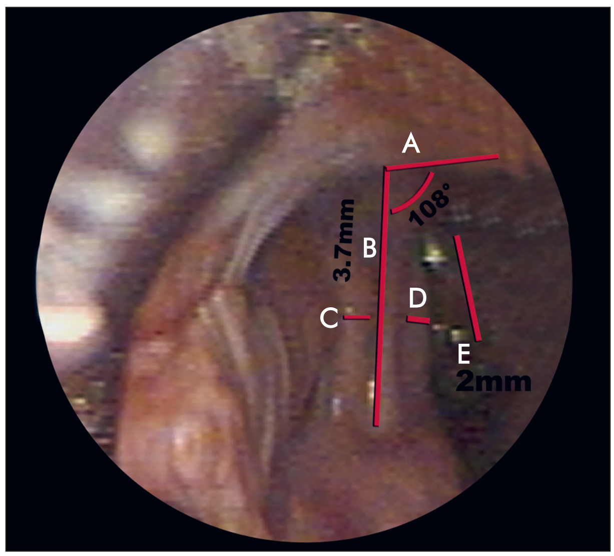

Figure 4. *The length of the 4th nerve in the cistern and the relationship of the SCA with the PCA and the angle of participation in the tentorium (right subtemporal view with 45° endoscopic view):* **A**. *the participation angle,* **B**. *the length of the 4th nerve,* **C**. *SCA,* **D**. *PCA,* **E**. *scale*

between the trochlear nerve and the superior cerebellar artery; 2. Distance between the trochlear nerve and the posterior cerebral artery; 3. Arising angle of the nerve from the brain stem; 4. Angle between the tentorium and the nerve; 5. Length of the nerve; 6. Diameter of the nerve; 7. Length of the nerve in ambient cistern. **Table 1** shows the results of the craniometric measurements.

The median infratentorial supracerebellar approach allowed exposure of the cisternal seg-

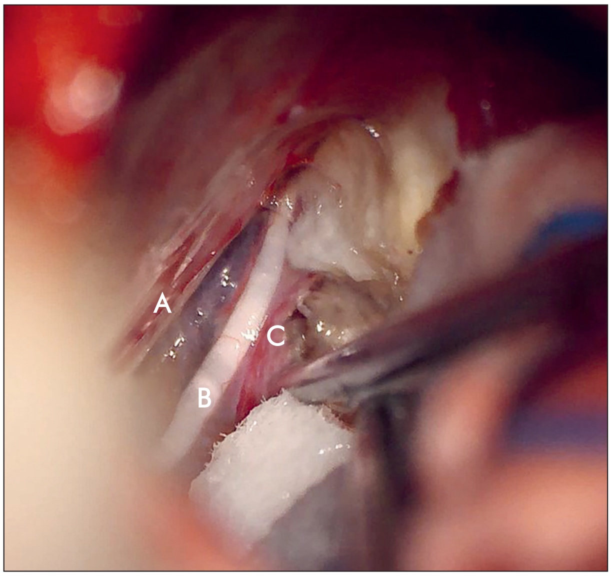

Figure 5. *Intraoperative relationship of the 4th nerve with cisternal PCA and SCA:* **A**. *SCA,* **B**. *4th nerve,* **C**. *PCA*

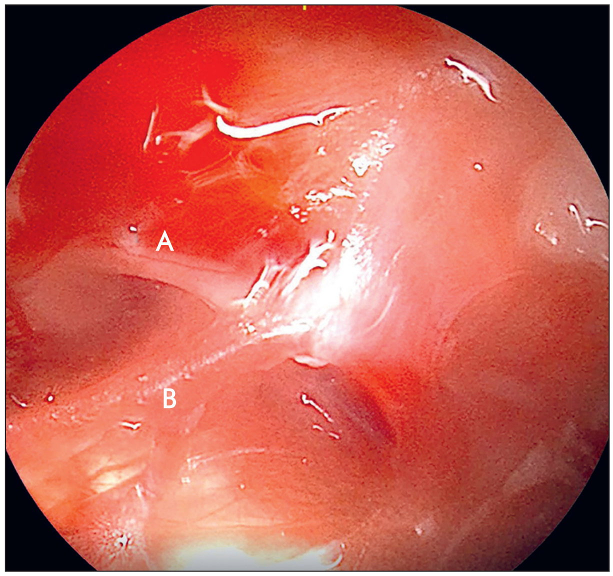

Figure 6. *Intraoperative endoscopic view of the relationship between the 4th nerve and the cisternal SCA:* **A**. *the 4th nerve,* **B**. *SCA*

ments (crural and ambient cisterns), including the origin of the nerve in the brain stem. The combined presigmoid-subtemporal transtentorial approaches provided visualization of the cisternal segment of the nerve and the free edge of the tentorium. In this study, the mean length and width of the trochlear nerve in the cisternal segment were 30.3 and 0.74 mm, respectively. The length of the trochlear nerve from its origin to its dural entrance was 37.2 mm, the tentorial dural entrance angle of the trochlear nerve and the exit angle of the trochlear nerve from the brain stem were 127.0 degrees and 54 degrees, respectively. The posterior cerebellar artery (PCA) to trochlear nerve distance in the mid ambient cistern and the superior cerebellar artery (SCA) to trochlear nerve distance in the mid ambient cistern were 5.8 mm and 3.7 mm, respectively **(Figures 1–4)**.

Discussion

The trochlear nerve has the longest course in the subarachnoid space, but it is also the thinnest cranial nerve[1, 7]. Its long intracranial course and thin structure make the nerve vulnerable to injury during surgery. The purpose of this cadaveric study was to have a safe access to the middle and posterior fossa regions with the help of craniometric and anatomical measurements.

The trochlear nerve usually arises as a single root from the inferolateral part of the inferior colliculus in the dorsal midbrain[2]. The trochlear nucleus is one of the smallest motor nuclei in the brain stem[8]. This nucleus is located near the midline at the level of the inferior colliculus and trochlear efferent fibers pass through the central gray matter posterolaterally, courses medially to reach the superior medullary velum, where they decussate[7, 9, 10].

The first part of the trochlear nerve is located laterally in the cerebellomesencephalic fissure. Then, the nerve crosses to the lateral side of the superior cerebellar peduncle. It courses along the quadrigeminal and ambient cisterns toward the tentorium on the upper side of the pons and joins the inferolateral side of the tentorium. In our study, the mean junction angle between the trochlear nerve and the tentorium was 127°.

Cisternal segment of the nerve can easily be seen when it courses in the subarachnoid space, but when it reaches the tentorial edge and turn downward, it becomes very difficult for surgeons to differentiate from the tentorium. After the posterior border of cerebral peduncle, the trochlear nerve joins the tentorium[7]. The conjoining angle is narrow and the nerve courses very close to the tentorium before the junction. Because of this, the tentorial incision must be planned very carefully and done before the posterior border of the cerebral peduncle. In this study, we intended to minimize the damage of the trochlear nerve by describing its conjoining angle to the tentorium. *Iaconetta* et al. divided the

Table 1. *Measurements of the determined parameters*

Anatomical landmark	Range	Mean	Median
SCA to trochlear nerve distance in the mid ambient cistern	2.7–6.1 mm	3.7 mm	3.25 mm
PCA to trochlear nerve distance in the mid ambient cistern	3.4–8.2 mm	5.8 mm	6.2 mm
Exit angle of the trochlear nerve from the brain stem	50.2–58.5 degree	54 degree	54 degree
Tentorial dural entrance angle of the trochlear nerve	99–154 degree	127.0 degree	128 degree
Origin of trochlear nerve to its dural entrance	32.2–42.6 mm	37.2 mm	36 mm
Lenght of trochlear nerve in the ambient cistern	19.4–41.8 mm	30.3 mm	30 mm
Thickness of trochlear nerve in the ambient cistern	0.44–1.03 mm	0.74 mm	0.75 mm

cisternal segment to quadrigeminal and ambient parts[11]. In the quadrigeminal cistern, the nerve courses along the lateral superior cerebellar peduncle in the subarachnoid space. It reaches the ambient cistern by piercing the cerebellar precentral membrane. In the ambient cistern, the trochlear nerve is adjacent to some important neurovascular structures like the SCA, PCA, and the basal vein of Rosenthal **(Figures 5, 6)**. It courses anteriorly and reaches its groove which is located on the inferior surface of the tentorium[12].

In our study, we found the mean distances between the SCA and the trochlear nerve (1st result) and the PCA and the trochlear nerve (2nd result) at the level of the ambient cistern (just before the posterior border of the cerebral peduncle) as 3.7 mm and 5.8 mm, respectively. The mean length of the trochlear nerve in the ambient cistern was 30.3 mm. The mean thickness of the trochlear nerve was 0.74 mm. The distal border of the cisternal segment was described as the point in tentorial groove before it became intradural[7, 9].

In previous studies, there was no mention of measurement of the arising angles of the nerves from the midbrain. All the angles were measured by using calipers, and it was calibrated in Surgimap software program. It was seen that all the nerves course asymmetrically. All of them were located inferior to the tentorial incisura and entered to the tentorium by rising in the cisterns. Courses of the nerves in the cisterns and craniometric relationships with adjacent neurovascular structures were determined. Since it is difficult to distinguish between the ambient and the crural cisterns anatomically, both were evaluated together under the name of ambient cistern in this study.

We believe that the information obtained from these measurements will be very helpful for the surgeons, especially in lateral infratentorial supracerebellar ipsilateral and contralateral approaches. In addition, the trochlear nerve–tentorium relationship will contribute to classical infratentorial supracerebellar and middle fossa approaches. The radiological imaging studies advancing and some high resolution sequences give adequate information about anatomical course of the trochlear nerve[13, 14]. But these sequences can be time consuming and not applicable to all cases[13, 14]. Although radiological assessments are very important in pre-operative evaluation, the cadaveric anatomical studies are very important in surgical aspect.

This study has some limitations. Endoscopic assistance helps us to reach and follow the nerves easily, but we cannot obtain 3D images. Microscopic studies can serve 3D images, but it is difficult to preserve anatomical structures under microscopic dissection. Although the use of fresh cadavers provided ease in terms of retraction, yet more satisfying images can be obtained by siliconized frozen cadavers.

Conclusion

In this study, we aimed to analyze the craniometric relationships between the trochlear nerve and the surrounding anatomical structures. Thus, we hope to improve the anatomical knowledge in the literature about the trochlear nerve and provide data to surgeons that help them navigate the trochlear nerve.

Accurate knowledge of the cisternal anatomy of the trochlear nerve and its relationship with the tentorium is important to prevent injury to the nerve during surgical procedures. With similar studies and continuous advances in the radiological techniques, we hope to discover more about the trochlear nerve.

CONFLICT OF INTEREST
The authors declared that there is no conflict of interest.

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