J Surg Med. 2020;4(10):853-856.
DOI: 10.28982/josam.813998

Research article
Araştırma makalesi

Journal of Surgery and Medicine
e-ISSN=2602-2079

Microsurgical anatomy of the anterior commissure through the anterior interhemispheric transcallosal approach to the third ventricle: An anatomical and morphological study

Üçüncü ventriküle anterior interhemisferik transkallozal yaklaşım yoluyla anterior komissürün mikrocerrahi anatomisi: Anatomik ve morfolojik bir çalışma

Seçkin Aydın [1], Ayşegül Esen Aydın [2], Necmettin Tanrıöver [3]

[1] University of Health Sciences, Okmeydani Training and Research Hospital, Department of Neurosurgery, Sisli, Istanbul, Turkey
[2] University of Health Sciences, Bakirkoy Prof. Dr. Mazhar Osman Training and Research Hospital for Psychiatric, Neurologic and Neurosurgical Diseases, Department of Neurosurgery, Bakirkoy, Istanbul, Turkey
[3] Istanbul University, Cerrahpasa Medical Faculty, Department of Neurosurgery, Fatih, Istanbul, Turkey

ORCID ID of the author(s)

SA: 0000-0001-5019-3435
AEA: 0000-0001-7444-8156
NT: 0000-0001-7628-9443

Corresponding author / Sorumlu yazar:
Seçkin Aydın
Address / Adres: Sağlık Bilimleri Üniversitesi, Okmeydani Eğitim ve Araştırma Hastanesi, Nöroşirurji Kliniği, Darülaceze Cad. No: 25, 34384, Şişli, İstanbul, Türkiye
E-mail: seckin047@hotmail.com

Ethics Committee Approval: The study protocol was approved by the institutional Ethics Committee of Istanbul University Cerrahpasa Medical Faculty (Decision No: 83045809/32140, Date: 9-3-2014). All procedures in this study involving human participants were performed in accordance with the 1964 Helsinki Declaration and its later amendments.
Etik Kurul Onayı: Bu çalışma İstanbul Üniversitesi Cerrahpaşa Tıp Fakültesi Hastanesi Etik Kurulu'nun tarafından onaylanmıştır (Karar No: 83045809/32140, Tarih: 9-3-2014). İnsan katılımcıların katıldığı çalışmalardaki tüm prosedürler, 1964 Helsinki Deklarasyonu ve daha sonra yapılan değişiklikler uyarınca gerçekleştirilmiştir.

Conflict of Interest: No conflict of interest was declared by the authors.
Çıkar Çatışması: Yazarlar çıkar çatışması bildirmemişlerdir.

Financial Disclosure: The authors declared that this study has received no financial support.
Finansal Destek: Yazarlar bu çalışma için finansal destek almadıklarını beyan etmişlerdir.

Published: 10/26/2020
Yayın Tarihi: 26.10.2020

Abstract
Aim: The third ventricle is a funnel-shaped cavity located deep in the brain and difficult to access with surgical approach. The anterior commissure is an anatomical structure located on the anterior wall of the third ventricle. This study aimed to demonstrate the use of the anterior interhemispheric transcallosal approaches to access the third ventricle, evaluate the microsurgical anatomy of the anterior commissure and investigate the morphological features of this region.
Methods: Eleven cadaveric brain specimens were dissected using microsurgical tools. Different anterior interhemispheric routes to the third ventricle were demonstrated, and stepwise dissections were performed to expose the limbs of the anterior commissure. Morphological measurements of the anterior commissure and the third ventricle were carried out.
Results: The anterior limb of the anterior commissure extends towards the anterior perforating substance, olfactory bulb, anterior olfactory nucleus and the orbitofrontal cortex. The posterior limb extends from the basal part of the caudate nucleus, passes below the substantia innominata and courses through the basal part of the putamen. It constitutes the major component of the anterior commissure and is composed of temporal and occipital fibers. The mean length of the anterior commissure body was 16.2 ± 4.2 (range 9.7–24.2) mm, while the mean width was 4.3 ± 0.7 (range 2.8–5.1) mm.
Conclusion: A better understanding of the microsurgical anatomy and morphometric features of the third ventricle and anterior commissure increases the success of surgical interventions and prevents possible complications in this region.
Keywords: Third ventricle, Anterior interhemispheric transcallosal approach, Anterior commissure, Microsurgical anatomy

Öz
Amaç: Üçüncü ventrikül, huni şeklinde derin yerleşimli bir beyin boşluğudur ve cerrahi yaklaşımlarla ulaşılması güçtür. Anterior komissür üçüncü ventrikülün anterior duvarında lokalize anatomik bir yapıdır. Bu çalışmada, üçüncü ventriküle ulaşmak için uygulanan anterior interhemisferik transkallozal yaklaşımların gösterilmesi, anterior komissürün mikrocerrahi anatomisinin incelenmesi ve bu bölgenin morfolojik özelliklerini incelenmesi amaçlanmıştır.
Yöntemler: 11 kadaverik beyin spesimeni mikrocerrahi aletlar kullanılarak diseke edildi. Üçüncü ventriküle ulaşmak için farklı anterior interhemisferik yollar gösterildi ve anterior komissürün bacaklarını ortaya koymak için kademeli diseksiyonlar yapıldı. Anterior komissür ve üçüncü ventrikülün morfolojik hesaplamaları yapıldı.
Bulgular: Anterior komissürün anterior bacağı, anterior perforan maddeye, olfaktör bulba, anterior olfaktör nükleusa ve orbitofrontal kortekse doğru uzanmaktadır. Posterior bacağı ise, kaudat nükleusun bazal kısmından uzanarak substansiya innominatanın altından geçmekte ve putamenin bazal kısmına doğru seyretmektedir. Anterior komissürün posterior bacağı, anterior komissürün majör komponentini oluşturmaktadır, ve temporal ve oksipital loblara giden liflerden oluşmaktadır. Anterior komissür gövdesinin ortalama uzunluğu 16,2 ± 4,2 (Aralık 9,7-24,2) mm, ve ortalama eni ise 4,3 ± 0,7 (Aralık 2,8-5,1) mm idi.
Sonuç: Üçüncü ventrikülün ve anterior komissürün mikrocerrahi anatomisi ve morfometrik özelliklerinin daha iyi anlaşılması bu bölgeye yapılacak cerrahi girişimlerde başarılı olmayı sağlar ve olası komplikasyonları önler.
Anahtar kelimeler: Üçüncü ventrikül, Anterior interhemisferik transkallozal yaklaşım, Anterior komissür, Mikrocerrahi anatomi

How to cite/Atıf için: Aydın S, Aydın AE, Tanrıöver N. Microsurgical anatomy of the anterior commissure through the anterior interhemispheric transcallosal approach to the third ventricle: An anatomical and morphological study. J Surg Med. 2020;4(10):853-856.

Introduction

Accessing the third ventricle of the brain often proves to be quite challenging due to its deep location and the functional importance of the adjacent anatomical structures [1]. The success of surgical interventions involving this region depends on a clear understanding of its microsurgical anatomy and principles.

The anterior interhemispheric transcallosal approach (AITA) is the most common method used to access lesions involving the third ventricle and can be used in combination with the transforaminal, interforniceal, subchoroidal, and transchoroidal routes [2,3].

The anterior commissure represents a key interhemispheric connecting structure that needs to be protected when approaching lesions affecting the anterior wall of the third ventricle. This study aims to demonstrate the use of an AITA to access the third ventricle, evaluate the microsurgical anatomy of the anterior commissure and investigates the morphological features of this region.

Materials and methods

Eleven cadaveric human brain specimens that kept in 10% formalin solution for at least 3 months were used. The arachnoid, pia mater and vascular structures were removed in the anatomy laboratory, and all dissections were performed using a surgical microscope (magnification 4–40x) and appropriate microsurgical tools. The specimens were stored in 75% alcohol solution between dissections.

First, the cingulate gyri were exposed using the interhemispheric space. Then, retractors were advanced towards the corpus callosum. A callosal incision, 1.5–2 cm in length, was created at a point approximately 2.5 cm posterior to the genu of the corpus callosum, depending on the access angle of the foramen of Monro, which was used as the central point of incision for all hemispheres. Thereafter, the third ventricle was accessed via the right lateral ventricle in all specimens.

The relationship between the anterior commissure and the approaches used were also demonstrated. Morphometric calculations were made using an electronic caliper between the anterior commissure and various anatomical landmarks.

This study was approved by the Research Ethics Committee of Istanbul University–Cerrahpasa, Cerrahpasa Medical Faculty (Number: 83045809/32140; Date: 9/3/2014).

Results

Although the anterior transcallosal pathway represents a common surgical corridor for accessing third ventricular lesions, various modifications can be made based on the location of the lesion. The modifications demonstrated in this study are listed below:

Transforaminal approach

This is the most common approach used to access tumors located in the anterior part of the third ventricle. The current study demonstrates access to the third ventricle from the foramen of Monro, followed by exposure of its anterior section by lifting the roof using dissection (Figure 1).

Interforniceal approach

This approach is typically suggested for accessing lesions in the anterior and middle sections of the third ventricle. Once adequate interforniceal exposure has been achieved, the velum interpositum can be opened and both internal cerebral veins may be retracted to expose the third ventricle floor (Figure 2).

Subchoroidal approach

The subchoroidal approach consists of opening the choroidal fissure by leaving the choroid plexus on the fornix side. However, this approach has almost been abandoned now as it typically requires sacrificing the thalamostriate vein which leads to serious complications due to venous hypertension (Figure 3).

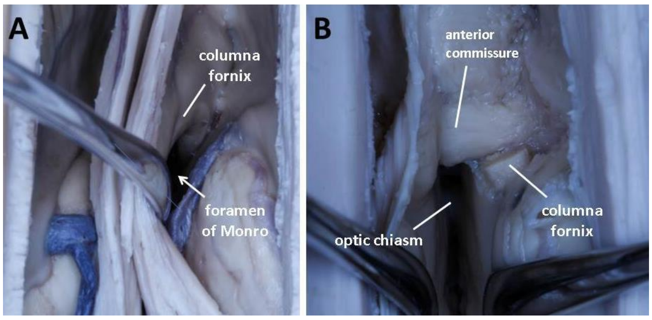

Figure 1: Transforaminal approach. A. Superior view of the foramen of Monro of the right lateral ventricle. The foramen of Monro was exposed more widely by retracting the upper border of the foramen of Monro and columna fornix. B. The anterior commissure is clearly exposed by cutting the right columna fornix.

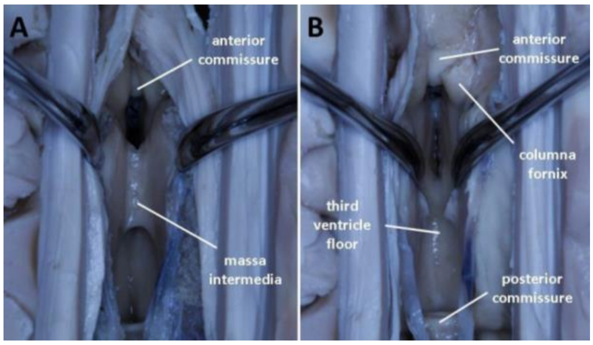

Figure 2: Interforniceal approach. A. Supeior view of the third ventricle after opening the septum pellucidum and corpus fornix in the midline. B. After the massa intermedia incision, the third ventricle floor was seen with bilateral retraction. The right columna fornix was cutted for a better view of the anterior commissure body.

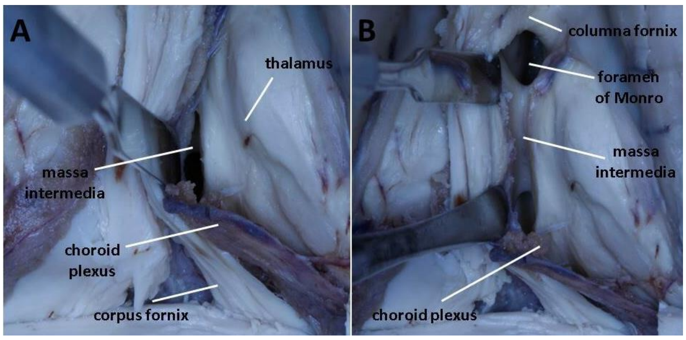

Figure 3: Subchoroidal approach. A. After the right choroid plexus was medialized with a retractor, access to the third ventricle was demonstrated. B. Third ventricle exposure was achieved with a double retractor. A large massa intermedia and columna fornix are seen.

Transchoroidal approach

The transchoroidal approach includes opening of the choroidal fissure along the tenia fornicis by starting at the posterior edge of the foramen of Monro and displacing the fornix medially and the choroid plexus to the opposite side to expose the deep third ventricle structures. Once the choroidal fissure has been opened and the fornix is retracted medially, the anatomical structures of the third ventricle were exposed (Figure 4).

Microanatomy of anterior commissure

The anterior leg of the anterior commissure includes axonal connections that enter the anterior perforating substance, coursing to the olfactory bulb, anterior olfactory nucleus and the orbitofrontal cortex. The posterior leg of the anterior commissure runs to the basal part of the caudate nucleus in a medio-lateral direction and then courses right behind the substantia innominata to a point below the anterior section of the globus pallidus. Most of the fibers go through the basal section of the putamen to its lateral border and then enter the white matter of the temporal lobe to the middle and inferotemporal region, with some fibers advancing further up to the occipital lobe [4] (Figure 5).

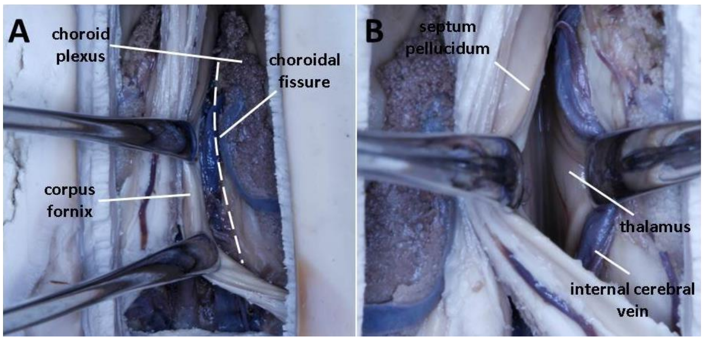

Figure 4: Transchoroidal approach. A. Superior view of the choroid plexus after the right corpus fornix is medialized. Choroidal fissure is shown in dashed lines. B. After the choroidal fissure was opened, the third ventricle was exposed.

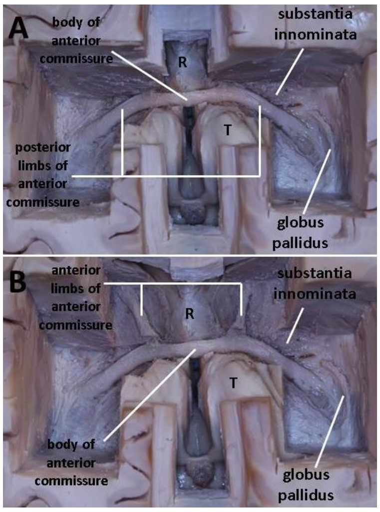

Figure 5: A. Anterior commissure body and bilateral posterior limb of the anterior commissure are seen from superior. The relationship between posterior limb and basal ganglia is also demonstrated. B. Anterior limb of the anterior commissure is exposed in superior view. R=Rostrum, T=Thalamus.

Morphological assessment

Important landmarks of the anterior commissure and third ventricle, including the cortical interhemispheric entry point where the anterior transcallosal approach was applied and the entry point to the third ventricle through which the corpus callosum was passed, were measured in the sagittal and axial planes (Figure 6). The mean, range and standard deviation values were calculated and are presented in Table 1.

The mean lengths from the entry point to the corpus callosum (EP-CC) and from the corpus callosum to the foramen of Monro (CC-FM) were 34.9 ± 3.1 (range 29.5–39.7) mm and 15.3 ± 4.8 (range 9.1–24.5) mm, respectively. The mean length of the anterior commissure body (ACL) was 16.2 ± 4.2 (range 9.7–24.2) mm, while the mean width (ACW) was 4.3 ± 0.7 (range 2.8–5.1) mm.

Approximately 90.9% (10/11) of the specimens in this study had a Massa intermedia, with only one specimen lacking it.

Table 1: Morphometric values of the third ventricle with anterior interhemispheric transcallosal approach focusing on the anterior commissure

Parameters	Mean and SD values (mm)	Range values (mm)
ACL	16.2 ± 4.2	9.7–24.2
ACW	4.3 ± 0.7	2.8–5.1
AC-FM	7.1 ± 0.8	5.5–8.4
AC-PC	24.9 ± 1.4	22.6–27.2
AC-R	17.5 ± 2.7	14.3–21.3
MIW	8.1 ± 2.8	3.7–12.2
MI-AC	9.3 ± 2.8	6.1-14.9
MI-PC	11.7 ± 1.9	8.1–14.1
Aq-AC	27.6 ± 3.6	22.1–32.1
Aq-FM	25.1 ± 3.4	20.1–29.8
FM-PC	23.1 ± 1.4	21.4–25.1
OC-AC	9.3 ± 0.9	7.4–10.1
OC-FM	14.5 ± 0.8	13.2–16.1
OC-PC	24.9 ± 1.3	22.7–26.9
EP-CC	34.9 ± 3.1	29.5–39.7
CC-FM	15.3 ± 4.8	9.1–24.5

SD: standard deviation, mm: millimeter, AC: anterior commissure, ACL: anterior commissure length, ACW: anterior commissure width, FM: foramen of Monro, PC: posterior commissure, R: rostrum, MI: Massa intermedia, MIW: Massa intermedia width, Aq: aquaduct, OC: optic chiasm, EP: entry point, CC: corpus callosum

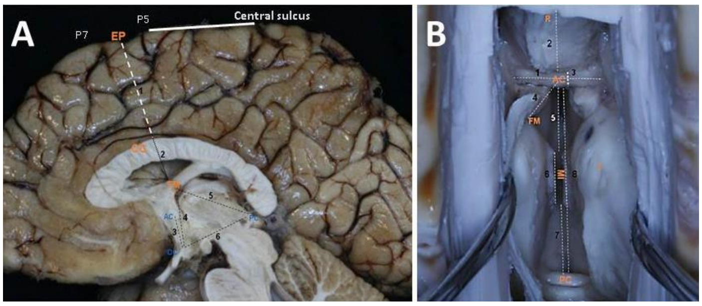

Figure 6: A. In order to determine the interhemispheric entry point in the sagittal plane, two points are determined 5 cm and 7 cm in front of the central sulcus. These are P5 and P7. The anterior transcallosal approach is made through this opening. This place is designated as Entry Point (EP). 1. The distance between the entry point and the corpus callosum (EP-CC), 2. The distance between corpus callosum and foramen of Monro (CC-FM), 3. The distance between the optic chiasm and the anterior commissure (OC-AC), 4. The distance between the optic chiasm and the foramen of Monro (OC-FM), 5. The distance between the Foramen of Monro and the posterior commissure (FM-PC), 6. The distance between the optic chiasm and the posterior commissure (OC-PC). B. Morphometric parameters of the third ventricle in the axial plane. 1. Anterior commissure length (ACL), 2. The distance between anterior commissure and rostrum (AC-R), 3. Anterior commissure width (ACW), 4. The distance between anterior commissure and foramen of Monro (AC-FM), 5. The distance between anterior commissure and massa intermedia (AC-MI), 6.Massa intermedia width (MIW), 7.The distance between massa intermedia and posterior commissure (MI-PC), 8.The distance between anterior commissure and posterior commissure (AC-PC).

Discussion

The third ventricle is a narrow funnel-shaped cavity and is located deep in the central nervous system, which is difficult to access. The transforaminal route is the most commonly used AITA to reach the third ventricle, mainly because colloid cysts, which typically originate from the anterior wall of the third ventricle, tend to constitute the majority of pathologies affecting this region [5,6]. Therefore, the current study focused on the anterior commissure, which is one of the most important structures located in the anterior wall of the third ventricle.

The anterior commissure is a paleopallial connection pathway developed in the embryological period from the telencephalon, and connects the two amygdaloid nuclei at the mesial temporal region. It is also an important anatomical landmark of the rhinencephalon and serves as a functional pathway between the two hemispheres [7].

There are limited studies on the detailed morphometry of the anterior commissure. Ozer et al. [8] measured the antero-posterior width and height of the anterior commissure and its distance from the pineal gland. Erturk et al. [9] investigated the morphometry of the anterior third ventricle using the subfrontal translaminaterminalis approach and reported FM-OC, AC-OC, OC-PC and ACW values similar to those seen in the current study. However, their ACL values were lower than those seen in the current study (3.89 ± 0.79 mm), and this could be attributed to the different approaches used. This suggests that the part of the anterior commissure encountered during the anterior transcallosal approach may be wider than that accessed using the subfrontal trans-lamina terminalis approach.

The Massa intermedia is a grey matter structure connecting the both thalamus from the midline, and little is known about its functions [10]. Previous studies have reported that approximately 24%–30% of people do not have a Massa intermedia [11,12], and only one out of 11 brain hemisphere samples examined in the current study did not have one.

The interhemispheric approach to the third ventricle requires crossing the commissural fibers which, if damaged, may lead to disconnection syndromes associated with major neurosurgical problems such as aphasia, left ideomotor apraxia, amnesia, and neglect [13-15]. Although the exact mechanism of disconnection syndromes is still unclear [16], the pathologies observed typically focus on two structurally important interhemispheric connection pathways, the corpus callosum and the anterior commissure.

Alternative pathways, particularly those involving the anterior commissure, play an important role in patients whose motor, language, cognitive and behavioral functions remain unaffected following incision of the corpus callosum [17,18]. The anterior commissure is also potentially associated with diffuse axonal injury, schizophrenia and cerebral tumor spread [19-21]. Fisher et al. [22] reported that anterior commissure hypertrophy develops due to re-routing in patients with corpus callosum agenesis. Also, DTI studies have shown that the anterior commissure may play a role more important than previously thought [18,23].

Patients with anterior commissure damage during surgery suffer from a delay in recognition, loss in ability to perform arithmetic calculations, problems with interpretation of abstract thoughts, and short-term memory loss [7,24,25]. Anterior commissurotomy decreases emotional awareness, social connectedness and interpersonal relationships, and can also lead to neurological disorders such as alexithymia [26,27]. However, direct stimulation of the anterior commissure during awake surgeries does not appear to produce any neurological findings, and partial excision along with the pathological lesion being treated has been shown to have no complications [28]. It is still unknown whether complete sacrifice of the anterior commissure with incision of the corpus callosum will lead to any neurological disorders. However, in their study involving monkeys, O'Reilly et al. [29] found that incision of the anterior commissure with the corpus callosum led to complete loss of the interhemispheric connection, as seen in the functional MRI, suggesting that special attention should be paid to preservation of the anterior commissure during surgeries requiring incision of the corpus callosum. In our opinion, this can only be achieved by developing a clear understanding of the anatomy of this region.

Limitations

This study had several limitations. Firstly, formalin fixation may have resulted in some shrinkage of the neural tissue and alteration of the ventricular system morphometry. However, a previous morphometric study comparing formalin-fixed brain samples to fresh ones reported no significant differences [30]. Secondly, this study only measured the anterior commissure body and not the anterior and posterior limbs as the aim was to focus on the part of the anterior commissure encountered during AITA and located in the anterior wall of the third ventricle.

Conclusion

The findings of this study emphasize the need to preserve neuronal pathways and critical neuro-anatomical structures during surgical interventions involving the third ventricle. Morphometric measurements of this region play a major role in the planning and success of surgical interventions, and the surgeon should have a clear understanding of the anatomy of the anterior commissure when using the anterior transcallosal approaches so as to avoid damaging it.

References

1. Rhoton AL Jr. The lateral and third ventricles. Neurosurgery. 2002 51[Suppl1]:207–71.
2. Hernesniemi J, Romani R, Dashti R, Albayrak BS, Savolainen S, Ramsey C 3rd, et al. Microsurgical treatment of third ventricular colloid cysts by interhemispheric far lateral transcallosal approach--experience of 134 patients. Surg Neurol. 2008 May;69(5):447-53; discussion 453-6.
3. Delfini R, Pichierri A. Transcallosal Approaches to Intraventricular Tumors. In: Cappabianca P, Iaconetta G, Califano L, eds. Cranial, Craniofacial and Skull Base Surgery. Milano: Springer; 2010. Pp.87-105.
4. Ribas EC, Yağmurlu K, de Oliveira E, Ribas GC, Rhoton A. Microsurgical anatomy of the central core of the brain. J Neurosurg. 2018 Sep;129(3):752-69.
5. Antunes JL, Louis KM, Ganti SR. Colloid cysts of the third ventricle. Neurosurgery. 1980 7:450-5.
6. Symss NP, Ramamurthi R, Rao SM, Vasudevan MC, Jain PK, Pande A. Management outcome of the transcallosal, transforaminal approach to colloid cysts of the anterior third ventricle: an analysis of 78 cases. Neurol India. 2011 Jul-Aug;59(4):542-7.
7. Lavrador JP, Ferreira V, Lourenço M, Alexandre I, Rocha M, Oliveira E, et al. White-matter commissures: a clinically focused anatomical review. Surg Radiol Anat. 2019;41:613–24.
8. Ozer MA, Kayalioglu G, Erturk M. Morphometric anatomy of anterior commissure, pineal body and massa intermedia. Medeniyet Med J. 2005;20(3):161-3.
9. Erturk M, Kayalioglu G, Ozer MA. Morphometry of the anterior third ventricle region as a guide fort he subfrontal (translaminaterminalis) approach. Neurosurg Rev. 2003 Oct;26(4):249-52.
10. Damle NR, Ikuta T, John M, Peters BD, DeRosse P, Malhotra AK, et al. Relationship among interthalamic adhesion size, thalamic anatomy and neuropsychological functions in healthy volunteers. Brain Struct Funct. 2017;222(5):2183-92.
11. Carpenter MB, Sutin J, editors. Human neuroanatomy, 8th ed. Baltimore: Williams & Wilkins; 1983.
12. Borghei A, Cothran T, Brahimaj B, Sani S. Role of massa intermedia in human neurocognitive processing. Brain Struct Funct. 2020;225:985–93.
13. Absher JR, Benson DF. Disconnection syndromes: an overview of Geschwind's contributions. Neurology 1993;43:862–7.
14. Demeter S, Rosene DL, Van Hoesen GW. Fields of origin and pathways of the interhemispheric commissures in the temporal lobe of macaques. J Comp Neurol. 1990 Dec 1;302(1):29-53.
15. Catani M, Howard RJ, Pajevic S, Jones DK. Virtual in vivo interactive dissection of white matter fasciculi in the human brain. Neuroimage. 2002 Sep;17(1):77-94.
16. Catani M, ffytche DH. The rises and falls of disconnection syndromes. Brain. 2005 Oct;128(Pt 10):2224-39.
17. Di Virgilio G, Clarke S, Pizzolato G, Schaffner T. Cortical regions contributing to the anterior commissure in man. Exp Brain Res. 1999 Jan;124(1):1-7.
18. Patel MD, Toussaint N, Charles-Edwards GD, Lin JP, Batchelor PG. Distribution and fibre field similarity mapping of the human anterior commissure fibres by diffusion tensor imaging. MAGMA. 2010 Dec;23(5-6):399-408.
19. Wilde EA, Bigler ED, Haider JM, Chu Z, Levin HS, Li X, Hunter JV. Vulnerability of the anterior commissure in moderate to severe pediatric traumatic brain injury. J Child Neurol. 2006 Sep;21(9):769-76.
20. Highley JR, Esiri MM, McDonald B, Roberts HC, Walker MA, Crow TJ. The size and fiber composition of the anterior commissure with respect to gender and schizophrenia. Biol Psychiatry. 1999 May 1;45(9):1120-7.
21. Mughal AA, Zhang L, Fayzullin A, Server A, Li Y, Wu Y, et al. Patterns of Invasive Growth in Malignant Gliomas-The Hippocampus Emerges as an Invasion-Spared Brain Region. Neoplasia. 2018 Jul;20(7):643-56.
22. Fischer M, Ryan SB, Dobyns WB. Mechanisms of interhemispheric transfer and patterns of cognitive function in acallosal patients of normal intelligence. Arch Neurol. 1992;49(3):271–7.
23. Peltier J, Verclytte S, Delmaire C, Pruvo JP, Havet E, Le Gars D. Microsurgical anatomy of the anterior commissure: Correlations with diffusion tensor imaging fiber tracking and clinical relevance. Neurosurgery. 2011;69:ons241–6.
24. Botez-Marquard T, Botez MI. Visual memory deficits after damage to the anterior commissure and right fornix. Arch Neurol. 1992 Mar;49(3):321-4.
25. Winter TJ, Franz EA. Implication of the anterior commissure in the allocation of attention to action. Front Psychol. 2014 May 19;5:432.
26. Bermond B, Vorst HC, Moormann PP. Cognitive neuropsychology of alexithymia: implications for personality typology. Cogn Neuropsychiatry. 2006 May;11(3):332-60.
27. Meza-Concha N, Arancibia M, Salas F, Behar R, Salas G, Silva H, et al. Towards a neurobiological understanding of alexithymia. Medwave. 2017 May 29;17(4):e6960.
28. Duffau H. Brain Mapping: From Neural Basis of Cognition to Surgical Applications. Wien: Springer-Verlag; 2011.
29. O'Reilly JX, Croxson PL, Jbabdi S, Sallet J, Noonan MP, Mars RB, et al. Causal effect of disconnection lesions on interhemispheric functional connectivity in rhesus monkeys. Proc Natl Acad Sci USA. 2013 Aug;110(34):13982-7.
30. Lang J, Stefanec P, Breitenbach W. Form and measurements of the third ventricle, visual pathway sections and oculomotor nerve. Neurochirurgia (Stuttg). 1983 Jan;26(1):1-5.

This paper has been checked for language accuracy by JOSAM editors.
The National Library of Medicine (NLM) citation style guide has been used in this paper.