Original Article

Microsurgical Anatomy of Medial Temporal Lobe in North-West Indian Population: Cadaveric Brain Dissection

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Abstract

Aim: The medial temporal lobe (MTL) is a highly complex neuroanatomical structure of tremendous neurosurgical importance. It is a common site for epilepsy, vascular lesions, and tumors. Owing to the critical location behind the sphenoid wing, it is more prone for traumatic contusion often with surgical implications. Hence, its microneurosurgical anatomy needs to be evaluated in detail. **Materials and Methods:** Twelve formalin-fixed human cadaveric brains from North-west Indian population were dissected under neurosurgical microscope and various dimensions of the MTL and their distance from important neurovascular structures were measured. **Results:** The MTL consists of important neural structures such as parahippocampal gyrus, uncus, hippocampus, temporal horn, and choroidal fissure. The average distance of tentorium from the uncus was 1.96 mm. The temporal horn and the inferior choroidal point were located from the anterior temporal pole at 22.9 mm and 30.9 mm, respectively. Important vessels that are intimately related to the MTL were anterior choroidal artery (AchA), posterior communicating artery, the P1 segment of posterior cerebral artery, and the M1 segment of middle cerebral artery. **Conclusion:** Complex anatomic and cytostructural organization makes the MTL unique. In this study, along with the descriptive anatomy, morphometric measurements of various structures were performed. The uncus and its relation to other neurovascular structures is well described in literature, but its exact distance from them as determined in this study is particularly helpful in guiding the surgeons while approaching in this area. Knowledge of the distance of the temporal horn from various surfaces is important while opening the temporal horn to avoid unnecessary damage to nearby structures.

Keywords: *Anatomy, cadaveric study, Indian, medial temporal lobe*

Introduction

The medial temporal lobe (MTL) is a highly complex neuroanatomical structure of tremendous neurosurgical importance. This is the area which is diseased, damaged, or dysfunctional in innumerable neurological and psychiatric disorders, but still many larger issues remain much less understood.

Temporal lobe (TL) is not only unique but also extremely complex in respect to its organization and its relation to important neurovascular structures of the brain. Histologically, it presents areas of different cortical organizations, starting from three-layered allocortex to six-layered neocortex, and this gradual transition from the primitive allocortex to a more recent isocortex plays an important role in making the TL the preferred site for certain tumors and epilepsy.[1] TL is a common site for vascular malformations such as arteriovenous malformations, cavernomas, and aneurysms involving nearby vessels.[2] Its location behind the sphenoid wing makes TL more prone for the development of traumatic contusions, often with surgical implications. TL is unique in many aspects including its architecture, relationship to various structures, and variation in anatomy from normal and thereof much neurosurgical importance, hence its microsurgical anatomy requires detailed evaluation and understanding.

Materials and Methods

The present study was conducted on the brains of 12 adult cadavers (male - 7, female - 5), obtained from the Department of Anatomy, PGIMER, Chandigarh, donated under body donation program. The dissections were made using OPMI® CS-NC, Carl Zeiss Meditec, Inc., USA, neurosurgical microscope (magnification ×3–×40), micro-neurosurgical equipment, and

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high-speed drill (Medtronic, Midas Res, USA). In some of the cadavers, colored (red) latex dye was injected into the bilateral cervical internal carotid arteries. All the brains were studied initially *in situ* after a large fronto-temporal craniotomy and then after removing it from the calvaria for better exposure of the medial temporal region. The various dimensions of the MTL structures and their distance from important vessels were measured using the digital Vernier callipers (Yuri-06, range 0–300 mm; graduation 0.01 mm) [Figure 1]. Relevant photographic documentation was done by direct recording from microscope and using high-resolution high-definition digital camera.

Important anatomical concepts that were analyzed include (1) the dimensions of important medial lobe structures which are relevant to surgeons navigating in this area (2) outlining the depth of temporal horn from different surfaces (3) measurement of distance of various neurovascular structures of the basal cisterns from medial cortical surface.

Results

After removal of the arachnoid membrane and lateral cortical leptomeningial vessels, surface topography of the TL was studied. The sylvian fissure was dissected and opened from the medial to lateral aspect, and insular contents were exposed. The optic nerve and the chiasm were exposed, and all the branches of the supraclinoid internal carotid artery (ICA) were dissected. The ICA bifurcation was delineated, the middle cerebral artery (MCA) was traced, and its branches were exposed and dissected inside the sylvian fissure. TL was elevated to expose the tentorium and their contents were seen from outside. After complete dissection, the brain was removed from the calvarium along with the relevant neurovascular contents to dissect the individual MTL structures. After the dissection of the extraventricular components, the temporal horn was opened along the whole length to expose the various intraventricular structures. The temporal horn was dissected up to the fornix along the inferior aspect of the corpus callosum. The vessels were dissected in the basal cistern and their relations to the MTL structures were noted. The detailed anatomy of the MTL structures is described below.

The parahippocampal gyrus

The parahippocampal gyrus (PHG) was located in the transitional area between the basal and mesial surface of the TL running in an antero-posterior direction. Anteriorly, it continued as the uncus and posteriorly, it continued along the posterior part of the splenium of the corpus callosum [Figure 2a]. The dimensions of the PHG were noted [Table 1]. The average width of the PHG was 12 mm in the anterior part at the level of uncal notch where it becomes continuous with the uncus and 8 mm in the posterior part just before its termination. The average length of the PHG was noted to be 50.5 mm. In the lateral aspect, the collateral sulcus separates the PHG from the rest of the TL. The length of the collateral sulcus was 133.58 mm. The

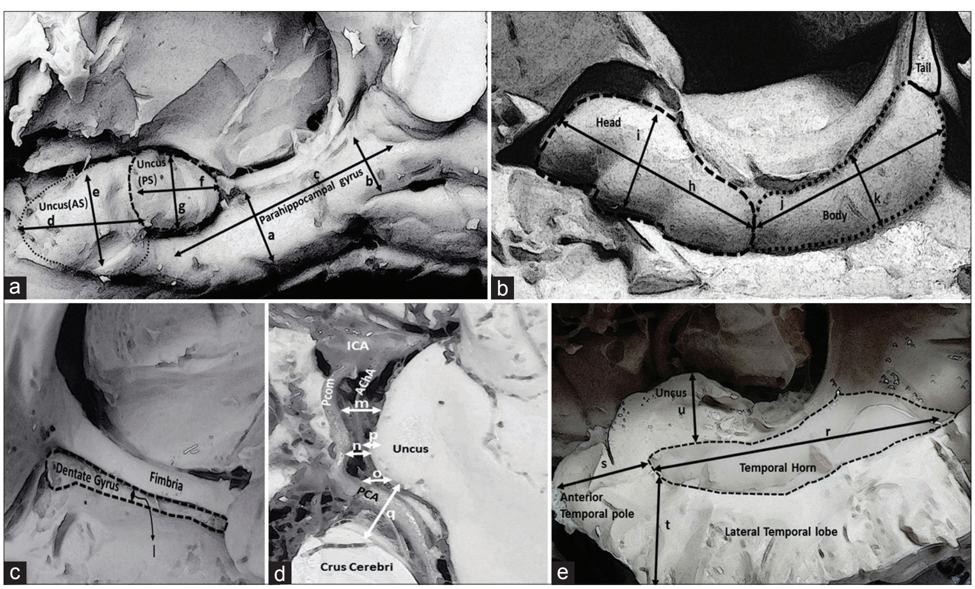

Figure 1: Techniques of measurement of medial temporal lobe structures. (a) Uncus and parahippocampal gyrus; (b) hippocampus; (c) dentate gyrus; (d) neurovascular structures of basal cistern; (e) temporal Horn. a = width of parahippocampal gyrus at the anterior part; b = width of the parahippocampal gyrus at the posterior part; c = length of parahippocampal gyrus; d = length of AS of uncus; e = width of AS of uncus; f = length of PS of uncus; g = width of PS of uncus; h = length of head of hippocampus; i = width of head of hippocampus; j = length of body of hippocampus; k = width of body of hippocampus; l = width of dentate gyrus; m = distance of proximal segment of Pcom (before piercing liliequist membrane) to uncus; n = distance of distal segment of Pcom (in interpeduncular cistern) to uncus; o = distance of P2 segment of posterior cerebral artery to uncus; *P* = distance of anterior choroidal artery from uncus; q = distance of crus cerebri form uncus; r = length of the temporal horn in its long axis; s = distance of the temporal horn from anterior temporal pole; t = distance of the temporal horn from the lateral temporal surface; u = distance of the temporal horn from the uncus. PHG: Parahippocampal gyrus, AS: Anterior segment, PS: Posterior segment

PHG in its medial aspect surrounds the brainstem along the free edge of the tentorium. The average distance of the free edge of tentorium from the PHG was 1.94 mm.

Uncus

The uncus was studied after removing the brain from calvaria [Figure 2b]. The dimensions of its anterior and posterior segments were measured [Table 2]. We found the uncus lying herniated in seven hemispheres out of 24 specimens (29%). The average distance of the free edge of tentorium from uncus was 1.96 mm. The average distance of the occulomotor nerve from posterior segment of the uncus was 2.02 mm (1.90 mm in male and 2.19 mm in female cadavers). The difference in distance between male and female cadavers was found to be statistically significant ($P = 0.003$). The distance of the apex of posterior segment of uncus from the crus cerebri was noted to be 10.19 mm. The dentate gyrus was exposed from the uncus till its termination behind corpus callosum and its average width was 2.03 mm.

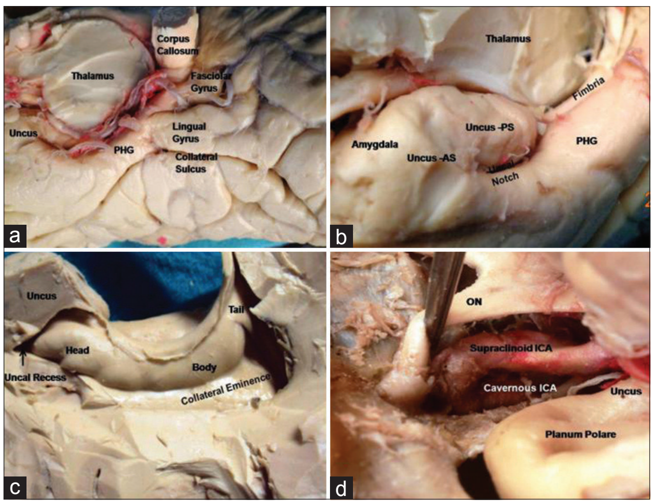

Figure 2: (a) The parahippocampal gyrus, (b) the uncus and its segments, (c) the temporal horn and hippocampus, (d) the supraclinoid internal carotid artery. PHG: Parahippocampal gyrus, AS: Anterior segment, PS: Posterior segment, ON: Optic nerve

The temporal horn

The temporal horn was opened from the middle temporal gyrus. The distance of the temporal horn from various aspects of the TL was measured [Table 3]. The average length of temporal horn was 52.00 mm. The average distance of temporal horn from lateral TL surface, uncus, and the anterior temporal pole were 22.01 mm, 12.19 mm, and 22.86 mm, respectively.

Hippocampus

The hippocampus was exposed after opening the temporal horn [Figure 2c]. The average length and width of the hippocampal head were 12.83 mm and 11.30 mm, respectively. The average length and width of the body were 22.95 mm and 7.94 mm, respectively [Table 4]. The choroidal fissure was exposed after tracing the choroid plexus inside the temporal horn. The distance of the inferior choroidal point from the anterior temporal pole was 30.90 mm [Table 5].

The vascular relationship of uncus

The average distance of ICA bifurcation from anteromedial surface of the uncus was 4.05 mm [Figure 2d]. Out of the four segments of MCA, only proximal part of the M1 segment was related to the anterior surface of the

Table 1: Dimensions of the parahippocampal gyrus and its relation

All distance (in mm)	Male (n=14)		Female (n=10)		Total (n=24)		P
	Mean	SD	Mean	SD	Mean	SD	
Width of the PHG in the anterior part	11.98	0.15	12.0	0.15	12.0	0.15	0.403
Width of the PHG in the posterior part	8.02	0.14	7.96	0.13	8.00	0.14	0.250
Length of the PHG	50.50	1.65	50.50	1.58	50.5	1.58	1.000
Distance of the tentorium from the PHG	1.95	0.12	1.92	0.19	1.94	0.15	0.576
Length of the collateral sulcus	134.28	3.07	132.60	2.50	133.58	2.91	0.168

PHG – Parahippocampal gyrus; SD – Standard deviation

Table 2: Dimensions of the uncus and its relations

All distance (in mm)	Male (n=14)		Female (n=10)		Total (n=24)		P
	Mean	SD	Mean	SD	Mean	SD	
Uncus length (anterior segment)	15.09	0.52	14.98	0.45	15.04	0.48	0.588
Uncus width (anterior segment)	9.89	0.51	10.27	0.55	10.05	0.55	0.103
Uncus length (posterior segment)	12.05	0.34	12.08	0.47	12.06	0.39	0.892
Uncus width (posterior segment)	8.02	0.31	7.90	0.29	7.97	0.30	0.324
Distance of occulomotor nerve from the uncus	1.90	0.23	2.19	0.15	2.02	0.24	0.003
Distance of tentorium from uncus	1.93	0.19	2.00	0.22	1.96	0.20	0.459
Distance of uncus from crus cerebri	10.23	0.55	10.14	0.58	10.19	0.55	0.687

SD – Standard deviation

uncus [Figure 3a and b]. The average distance of MCA bifurcation from uncus was 12.40 mm. After the origin of posterior communicating artery (PcomA) from the dorsomedial or dorsolateral surface of the ICA, it was seen running posteromedially below the optic tract and above the occulomotor nerve, entering into the interpeduncular cistern to join the posterior cerebral artery (PCA) [Figure 3c and d]. The PcomA was not in a close relation to the uncus. The distance of uncus from the proximal part of the PcomA, just after its origin was 4.75 mm and from the distal part was 3.43 mm. The PcomA was found on the medial side of the occulomotor nerve in 84% of cases and lateral in 16% of cases. The anterior choroidal artery (AChA) was seen arising just distal to the origin of PcomA, going posterosuperiorly and medially to reach the optic tract. Here, it was related to anteromedial surface of the uncus [Figure 3c and d]. At the posterior edge of the intralimbic gyrus, it entered the temporal horn. The average distance of the AChA from uncus was 2.07 mm. The initial P1 segment of the PCA was not related to the uncus. The P2A segment was seen in the posteromedial aspect of the uncus just inferior to the AChA [Figure 4a] separated by 2.02 mm [Table 5].

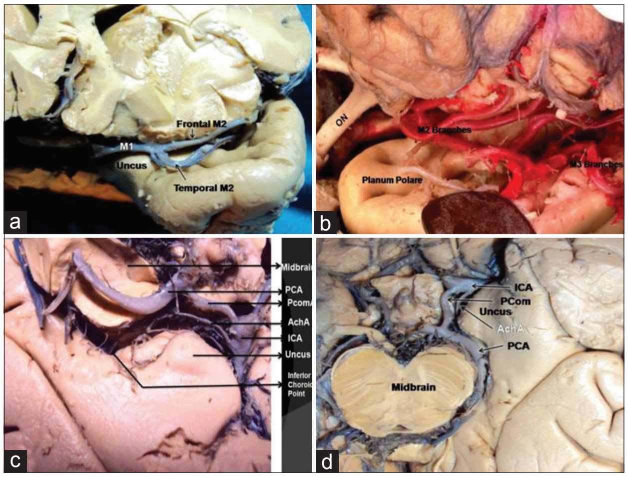

Figure 3: (a) The middle cerebral artery bifurcation and its relation to uncus, (b) middle cerebral artery branches in sylvian fissure, (c and d) posterior communicating artery and anterior choroidal artery in relation to uncus. ON: Optic nerve

Discussion

The MTL is formed by three longitudinal strips of neural tissue which are interlocked with the hippocampal

Table 3: Temporal horn dimensions and its distance from various surfaces

All distance (in mm)	Male (*n*=14)		Female (*n*=10)		Total (*n*=24)		*P*
	Mean	SD	Mean	SD	Mean	SD	
Length of the temporal horn	51.74	2.78	52.40	2.27	52.00	2.55	0.529
Distance of the temporal horn from the lateral temporal surface	21.72	2.35	22.42	0.36	22.01	1.81	0.365
Distance of the temporal horn from uncus	12.16	0.71	12.23	0.57	12.19	0.64	0.812
Distance of the temporal horn from anterior temporal pole	22.80	0.477	22.95	0.82	22.86	0.63	0.597

SD – Standard deviation

Table 4: Dimensions of the hippocampus and the dentate gyrus

All distance (in mm)	Male (*n*=14)		Female (*n*=10)		Total (*n*=24)		*P*
	Mean	SD	Mean	SD	Mean	SD	
Hippocampus head length	12.88	0.52	12.88	0.50	12.83	0.50	0.979
Hippocampus head width	11.30	0.53	11.29	0.74	11.30	0.61	0.948
Hippocampus body length	23.10	0.68	22.76	0.79	22.95	0.73	0.272
Hippocampus body width	7.84	0.47	8.12	0.39	7.94	0.46	0.113
Width of dentate gyrus	2.09	0.38	1.96	0.30	2.03	0.35	0.374

SD – Standard deviation

Table 5: Vascular relation of the uncus

All distance (in mm)	Male (*n*=14)		Female (*n*=10)		Total (*n*=24)		*P*
	Mean	SD	Mean	SD	Mean	SD	
Distance of ICA bifurcation from uncus	4.07	0.35	4.01	0.22	4.05	0.30	0.602
Distance of MCA bifurcation from uncus	12.36	0.58	12.45	0.55	12.40	0.56	0.723
Distance of Pcom proximal part from uncus	4.73	0.49	4.79	0.52	4.75	0.49	0.799
Distance of Pcom distal part from uncus	3.38	0.68	3.51	0.62	3.43	0.65	0.655
Distance of PCA from uncus	2.02	0.41	2.03	0.34	2.02	0.37	0.993
Distance of AChA from uncus	2.00	0.35	2.17	0.24	2.07	0.31	0.219
Distance of inferior choroidal point from temporal pole	31.00	2.25	30.77	1.81	30.90	2.04	0.792

SD – Standard deviation; ICA – Internal carotid artery; MCA – Middle cerebral artery; PCA – Posterior cerebral artery; Pcom – Posterior communicating artery; AChA – Anterior choroidal artery

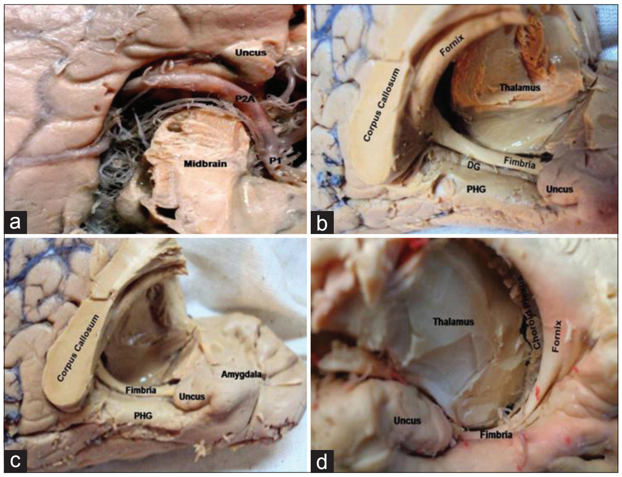

Figure 4: (a) Posterior cerebral artery in relation to uncus, (b) the fimbria, dentate gyrus, and their relations, (c) the amygdala, (d) the choroidal fissure. PHG: Parahippocampal Gyrus, DG: Dentate gyrus

formation and amygdala and are located one above the other. The PHG forms the most inferior component also called the subicular zone, the middle strip is formed by a narrow strip of gray matter in the medial aspect of hippocampal formation, the dentate gyrus, and the most superior component is formed by a white band that contains the fibers emerging from the hippocampal formation, called the fimbria.

The medial temporal lobe structures

The parahippocampal gyrus

The PHG in its anterior extent turns medially and posteriorly to form the uncus. The anterior calcarine sulcus often intersects the PHG at its posterior portion just below the splenium of corpus callosum, where it divides into two parts, the anterior part continues into the isthmus of cingulate gyrus and the posterior part continues inferiorly as the lingual gyrus [Figure 2a]. Superiorly, it is separated from the dentate gyrus by the hippocampal sulcus, anteriorly from the posterior segment of uncus by the uncal notch, and limited posterolaterally by the collateral sulcus. The PHG encircles brainstem along with the tentorial edge to constitute the tentorial incisura.[3] Various studies have been performed to correlate PHG atrophy with Alzheimer's disease and schizophrenia. Volumetric assessment of the PHG has been done using MRI in patients with Alzheimer's disease.[4,5] Postmortem studies have also been carried out to access the volume of the PHG to document asymmetry in patients with schizophrenia.[6] Our literature search did not reveal any anatomic study to define the linear measurements of the PHG. The linear dimensions of the PHG as measured in this study have been depicted in Table 1.

The uncus

The uncus is formed by anterior continuation of the PHG and is separated from it by the uncal notch [Figure 2b]. Superiorly, the uncus blends with the globus pallidus. Along its medial aspect, it normally lies just below the tentorial hiatus.

The uncus is composed of five small gyri, two in the anterior segment and three in the posterior segment.[7] The anterior segment contains the semilunar and the ambient gyri and the posterior segment contains the uncinate gyrus, intralimbic gyrus, and the band of Giacomini.[8] The inferior choroidal point, which lies in the postero-superior relation of the uncus, corresponds to the site where AChA enters the temporal horn through the choroidal fissure. The choroidal fissure which despite being an embryological fissure is an important structure that guides the neurosurgeon while disconnecting the TL from the rest of the brain.

From the neurosurgical view point, the dimensions of uncus are important for various reasons. The amygdala is entirely located in the boundaries of the uncus and hence resection of the uncus is a part of amygdalohippocampectomy for epilepsy due to MTL sclerosis. The transsylvian-transcisternal approach for the MTL lesions and for the anterior basal cisterns requires extensive opening of the sylvian fissure and the basal cisterns.[9] The AchA is traced from its origin to the inferior choroidal point. It is difficult to visualize the inferior choroidal point before resection of the medial part of the uncus because it lies hidden behind the apex of the uncus. Various studies have described the anatomical relationship of the uncus to the important neurovascular structures of the basal cistern, namely occulomotor nerve, tentorium, crus cerebri, ICA, AchA, PcomA, and the PCA.[3,10-14] To our knowledge, the distance of these structures form the uncus has not been described previously. The measured values in this study are depicted in Tables 2 and 5. Out of all segments of the ICA, only the terminal choroidal segment near its bifurcation and of MCA, only the proximal half of the M1 segment are related to the mesial TL [Figure 3a]. Though the PcomA is not in direct relation to the uncus, in certain cases, it is related to the anteromedial surface of the uncus and the uncal notch [Figure 3c and d]. The PcomA was lying medial to the occulomotor nerve in 86% of the cases. The AchA in its initial part runs in the medial relation to the anteromedial surface of the uncus. In the crural cistern, it lies in between the superior part of the posteromedial surface of the uncus and the crus cerebri before entering the temporal horn. The origin of the AChA is variable and depends on the height of the bifurcation of the ICA, however the entry point of the choroidal artery into the choroidal fissure in the TL is constant. This important inferior choroidal point can be located at around 3 cm from the anterior temporal pole in its medial border. The PCA, the terminal branch of posterior circulation, is divided into four segments.[15] The P1 segment is entirely cisternal and is not directly related to any part of the medial temporal structures, whereas the P2A segment, while turning around the crus cerebri, is related to the posteromedial segment of the uncus [Figure 4a]. The PCA lies in direct relation to the hippocampal sulcus and the anterior portion of the PHG. The uncus in its medial aspect lies in close relation to the P2A segment, the free edge of the tentorium, and the occulomotor nerve that characterizes the various symptoms and signs of the uncal herniation produced by raised intracranial pressure. In this study, the distance of the occulomotor nerve from the uncus was less in males as compared to females (1.9 mm vs. 2.19 mm, $P = 0.003$). This may have clinical implications in terms of early development of pupillary symptoms in male patients during tentorial herniation as compared to female patients. However, this finding requires validation with dissection of more number of cadavers.

The dentate gyrus

The dentate gyrus derives its name because of its tooth-like elevations and the denticulations, which are prominent mainly on its anterior and middle portions. It runs parallel in an interlocking fashion with the hippocampus.[7] It is separated from the fimbria of fornix which lies superiorly by the fimbrodentate sulcus; and in its inferior aspect, it is separated from the PHG by the hippocampal sulcus [Figure 4b].

The hippocampus

The hippocampus forms the main component of the intraventricular part of the medial temporal region and lies over the medial aspect of the floor of the temporal horn [Figure 2c]. It has got three parts, the head, body, and the tail.[5] The head of the hippocampus is the anterior most part in the medial aspect of temporal horn and is free of choroid plexus and is formed by three or four digitations, which is thought to be because of some developmental arrest during the forward migration of the hippocampus. In its superior aspect, the head of the hippocampus is related to the amygdala, which lies in the anterior and medial aspect.[7] The choroidal fissure where the fimbria and the choroid plexus originate marks the origin of the body of the hippocampus.[16] At the level of the atrium, the tail of the hippocampus starts, which becomes more slender as it continues and blends with the medial part of the floor of the atrium.[17] Campero *et al*. measured the length of the hippocampus to be approximately 5 cm long.[9] In this study, we separately described the length and width of the head and body of the hippocampus, and the results are in agreement with previous studies.

The fimbria

The alveus, which is the white matter covering the ventricular surface of the hippocampus, thickens along the medial edge of the hippocampus to form the fimbria. The fornix passes posteriorly to form the crus which wraps around the posterior surface of the pulvinar of the thalamus and bends superomedially toward the lower surface of the splenium of the corpus callosum [Figure 4b].

The amygdala

The amygdala forms an important component of the limbic system. It is divided into the temporal and extratemporal amygdala.[7] The former is otherwise called principal amygdala, and is located in the TL within the boundaries of uncus and the latter is also called extended amygdala, which is located in the primordial floor of the lateral ventricle. Superiorly, the principal amygdala blends into globus pallidus and in its inferior part, it is related to the hippocampus, where it bulges into the anteromedial aspect of the temporal horn and fuses with the head of the hippocampus [Figure 4c].

The choroidal fissure

The choroidal fissure is the site of attachment of the choroid plexus in the lateral ventricle. It is a cleft-like fissure that is located between the thalamus and the fornix, which extends from the foramen of Monro through the body, atrium, and the temporal horn of the lateral ventricle [Figure 4d].[18] The choroidal fissure ends at the inferior choroidal point, where the AChA enters the temporal horn and the inferior ventricular vein exits the temporal horn to join the basal vein of Rosenthal. In the temporal horn, the choroidal fissure can be easily identified by following the choroid plexus in the medial wall. It is one of the most important landmarks for the neurosurgeons in the TL surgery as all the structures that lie in the lateral aspect of the choroidal fissure is the TL *per se* and can be removed without endangering the vital areas, whereas the structures that lie in the medial aspect of the choroidal fissure belong to the thalamus and should not be removed.

Conclusion

The MTL is unique of its own because of its complex anatomic and cytostructural organization. It serves many of the important functions such as the human behavior, memory, learning process, and many of the visceral functions and autoregulation. It is involved in many disease processes including tumors, vascular malformations, aneurysms, and neuropsychiatric disorders. This is often the site of structural variations, which are the substrates of TL epilepsy. This study is an attempt to describe the MTL microanatomy, its relationship to adjacent neurovascular structures with their morphometric measurements. The uniqueness of this study is the description of the distance of uncus to adjoining structures which will be beneficial for neurosurgeons while approaching this area. Again the knowledge of the distance of the temporal horn from various surfaces is important while opening the temporal horn to avoid unnecessary damage to nearby structures. The measured parameters were compared to the literature already available and we did not find any gross anatomic variation in our study group which comprised the North-west Indian population.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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