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Neuroanatomical Study

Analysis of the anatomy of the Papez circuit and adjoining limbic system by fiber dissection techniques

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ABSTRACT

Fiber dissection techniques were used to study the limbic system, in particular the Papez circuit. The course, length and anatomical relations of the structures that make up the Papez circuit were delineated. Ten previously frozen and formalin-fixed cadaveric human brains were used, and dissected according to the fiber dissection techniques of Klingler et al. (*Schweiz Arch Neurol Psychiatry* 1935;**36**:247–56). The primary dissection tools were thin and curved wooden and metallic spatulas with tips of varying sizes. We found that the Papez circuit (mean length: 350 mm) begins in the hippocampus and continues into the fornix to reach the mamillary body. From there, the mamillothalamic tract continues to the anterior nucleus of the thalamus, which in turn connects to the cingulum by means of anterior thalamic radiations (mean length: 30 mm). The cingulum courses around the corpus callosum to end in the entorhinal cortex, which then projects to the hippocampus, thus completing the circuit. The average length and breadth of the mamillothalamic tract was 18 mm and 1.73 mm respectively. The average length of the cingulum was 19.6 cm and that of the fornix was 71 mm. The entire circuit was anatomically dissected first *in situ* in the hemisphere and was then reconstructed outside after removing its various components using fine fiber dissection under a surgical microscope. We found that fiber dissection elegantly delineates the anatomical subtleties of the Papez circuit and provides a three-dimensional perspective of the limbic system. Intricate knowledge of the anatomy of this part of the brain aids the neurosurgeon while performing epilepsy surgery and while approaching intrinsic brain parenchymal, ventricular and paraventricular lesions.
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1. Introduction

The limbic system is among the most complex and least understood parts of the nervous system. The term "limbus" means "border" or "margin" in Latin. This region of the brain was first pictured by Thomas Willis and he referred to it as "the limbus" as early as 1664.[1] In 1878, Paul Broca referred to it as "le grande lobe limbique" and described it as a cortical ring surrounding the hilus of the hemispheres.[2] James Papez postulated that the anatomical basis of emotions was found in the hypothalamus, anterior thalamic nuclei, cingulate gyrus, hippocampus and in their interconnections.[3] MacLean, in 1949, termed these cortical and subcortical systems and their fiber connections as "the limbic system".[4] Using silver degeneration techniques, Nauta extended the limits of the limbic system to include the midbrain.[5]

We have used the fiber dissection technique to depict the various components of the limbic system, in particular the Papez circuit. To our knowledge, fiber dissection techniques have not been used to their potential in evaluating and studying the microneurosurgical anatomy of this region.

2. Materials and methods

2.1. Preparation

The preparation of cadaveric brain specimens and dissection techniques were based on Klingler et al.[6] Ten normal human cerebral hemispheres were fixed in 10% formalin for 30 days. They were then frozen at −10 °C for three weeks to four weeks. The hemispheres were then allowed to thaw under water for 24 hours.[7,8]

2.2. Tools

The dissection was done with the aid of the operating microscope (6–40× magnification). The hemispheres were stored in 4% formalin between the dissection sessions. Our primary dissection tools were hand-made wooden spatulas with different sized spatula tips for superficial and deep dissection. The dissection was commenced from the medial surface of the cerebrum. Photographs were taken at each step of the dissection to demonstrate the anatomy.

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2.3. Medial to lateral dissection of the white matter

For anatomical delineation of the Papez circuit and the limbic system, a medial cerebral hemispheric approach was used (Fig. 1). The cerebral hemispheres were bisected in the midline through the corpus callosum. The medial and lateral longitudinal striae were identified on the surface of the corpus callosum before splitting the brain (Fig. 2). Major anatomical landmarks on the medial surface of the cerebral hemisphere were identified (Fig. 1). The ependymal coverings over the medial surface of the thalamus and the hypothalamus were peeled off carefully. The dissection was then begun with coring off of the gray matter of the thalamus (Fig. 3). The mamillothalamic tract was identified running upward from the mamillary body. The average length of the mamillothalamic tract was 18 mm (17.4–18.2 mm) and its breadth was 1.73 (1.6–1.8 mm). The tract was traced carefully till it was seen entering the anterior nucleus of the thalamus. The mamillotegmental tract was identified emerging from the mamillary body and going up to the midbrain tegmental nuclei ventral to the aqueduct. Subsequent to this the gray matter of the cingulate gyrus above the corpus callosum was cored out and the cingulum was identified, and traced anteriorly till its culmination in the subcallosal area and the paraterminal gyrus. Posteriorly, the cingulum narrowed above the splenium into the isthmus of the cingulum and then continued into the medial temporal lobe to end as the radiation of the cingulum which could be identified after removal of the parahippocampal gray matter. After tracing the whole length of the cingulum, the fibres of the cingulum entering into the frontal and parietal cortices were traced. The average length of the cingulum was 19.6 cm (19–20.4 cm).

Attention was now turned to the mesial temporal brain. The gray matter of the parahippocampal gyrus was removed to visualize the subiculum, dentate gyrus and fimbria of the fornix (Fig. 4). The gray matter was traced posteriorly and superiorly till it continued into the crus of the fornix. The body of the fornix was separated from the under-surface of the corpus callosum by blunt dissection. The body of the fornix was then traced anteriorly into the columns of the fornix, which ended in the mamillary body (Fig. 5). The columns of the fornix had an average length of 21.3 mm (20–23 mm) and an average breadth of 2.3 mm (2–2.6 mm). The average distance between the mamillothalamic tract and the fornix was 6.4 mm (6–7 mm). To complete the circuit, the continuation of the mamillothalamic tract was traced to the cingulum. The corpus callosum was removed carefully, avoiding damage to the cingulum (Fig. 6). The caudate head and body in the floor of the lateral ventricle were visualized. The stria terminalis was seen running between the thalamus and the caudate nucleus. The ependyma over the caudate head was removed. The whole caudate head was then lifted off in one piece to reveal the underlying anterior thalamic fibers radiating from the anterior nucleus of the thalamus and entering into the undersurface of the cingulum (Figs 7 and 8). The average length of the anterior thalamic radiations from the anterior nucleus of the thalamus to the point where they entered the cingulum was 3 cm. These fibers intermingled with the fibers of the anterior limb of the internal capsule and transverse fibers of the corpus callosum. This completed the dissection and isolation of the Papez circuit, which begins at the hippocampus, continues as the fimbria and fornix and terminates into the mamillary body. From the mamillary body the mamillothalamic tract then reaches the cingulum, which turns around the splenium of the corpus callosum to end as the radiation of the cingulum into the hippocampus, thus completing the loop.

Further dissection was then continued in the basal forebrain region. The olfactory tract was identified and observed splitting into the medial and lateral olfactory striae (Fig. 9). The medial olfactory stria was traced and was seen to end in the subcallosal gyrus. The lateral olfactory stria ended in the piriform cortex and the amygdala. The anterior perforated substance was identified between the medial and lateral olfactory striae. Deeper dissection was then performed to trace the anterior commissure. The anterior commissure was identified anterior to the column of fornix. The entire length of the anterior commissure was traced in both the hemispheres (Fig. 10). The average length of the anterior commissure on one side was 39 mm (37–40 mm) and the total length was 78 mm (74–80 mm). The mean breadth of the anterior commissure was 3 mm (3–3.3 mm). The various components of the limbic system were then removed using fine dissection and a reconstructed model was made (Fig. 11).

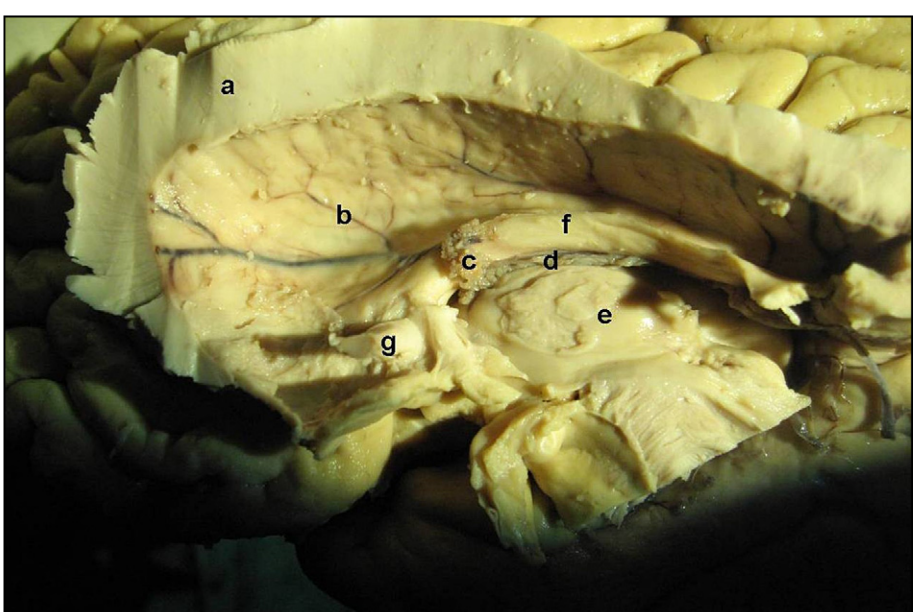

Fig. 1. Photograph of the medial view of the cerebral hemisphere showing the various anatomical landmarks: a, corpus callosum; b, frontal horn of lateral ventricle; c, choroid plexus in the choroidal fissure; d, choroidal fissure; e, thalamus; f, fornix; g, anterior commissure. (This figure is available in colour at www.sciencedirect.com.)

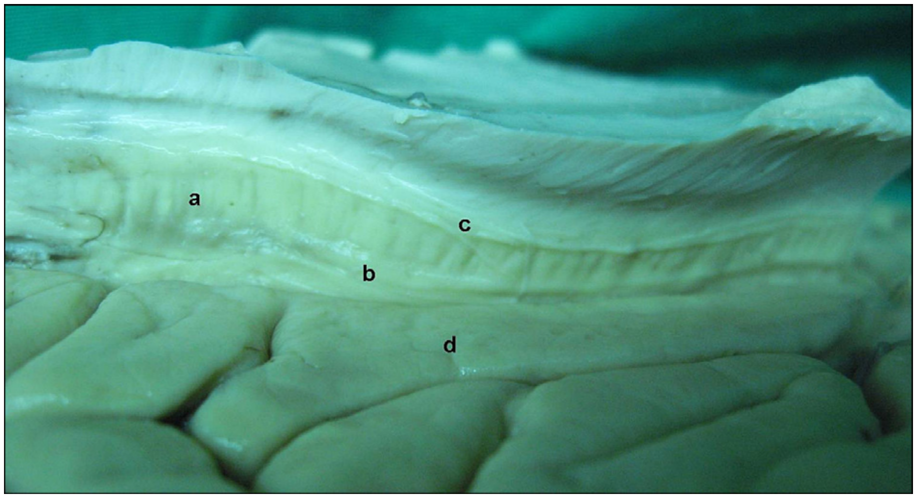

Fig. 2. Photograph of the superior view of the corpus callosum: a, corpus callosum; b, indusium griseum; c, longitudinal striae; d, cingulate gyrus running above the corpus callosum. (This figure is available in colour at www.sciencedirect.com.)

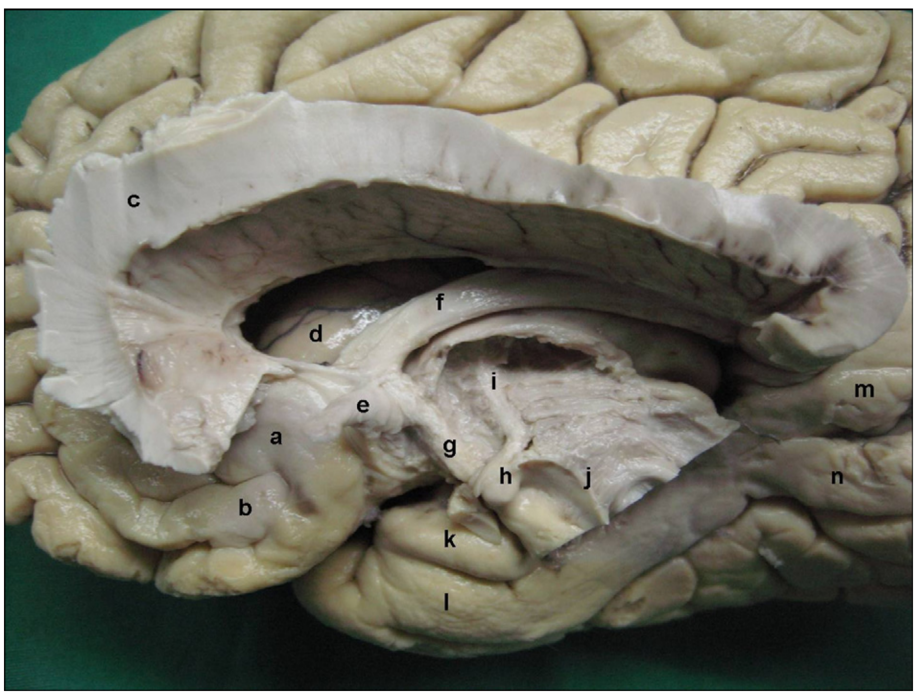

Fig. 3. Photograph of the dissection of the medial aspect of the hemisphere: a, paraterminal gyrus; b, subcallosal gyrus; c, corpus callosum; d, caudate head in frontal horn of lateral ventricle; e, anterior commissure; f, body of fornix; g, columns of fornix; h, mamillary body; i, mamillothalamic tract; j, mamillotegmental tract; k, uncus; l, parahippocampal gyrus; m, parahippocampal gyrus continuing as cingulate gyrus superiorly; and as n, lingual gyrus inferiorly. (This figure is available in colour at www.sciencedirect.com.)

3. Results and discussion

The limbic system is phylogenetically one of the more primitive parts of the brain and is composed of both gray and white matter. The gray matter component of the limbic system is composed of the hippocampal formation, amygdaloid nuclei, hypothalamus, nucleus accumbens, cingulate cortex, areas of the prefrontal cortex, and nuclei of the midbrain. The fiber bundle components of the limbic system include the cingulum, longitudinal striae, fornix, anterior commissure, mamillothalamic and mamillotegmental tracts, stria terminalis, striae medullaris thalami, diagonal band of Broca, fasciolus retroflexus, ansa peduncularis, dorsal longitudinal fasciculus and the medial forebrain bundle.[9,10]A brief description of the key components of the limbic system is given below.

3.1. Parahippocampus

The parahippocampal gyrus lies at the junction of the medial and inferior portions of the temporal lobe. Anteriorly and medially it curves to form the uncus. Laterally and anteriorly the parahippocampal gyrus is limited by the rhinal sulcus, which marks the lateral extent of the entorhinal area of the parahippocampal gyrus. The entorhinal area has many afferent and efferent connections with the hippocampus and the association areas of the cortex

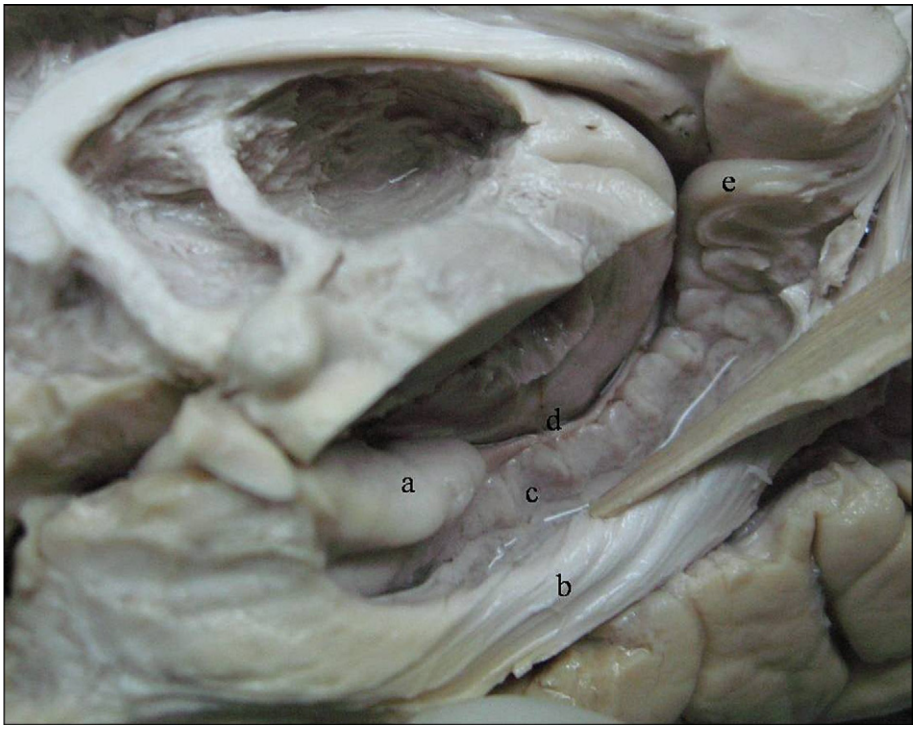

Fig. 4. Photograph of the dissection of the mesial temporal structures: a, hippocampus; b, radiation of the cingulum; c, dentate gyrus; d, fimbria; e, fasciolar/subsplenial gyrus. (This figure is available in colour at www.sciencedirect.com.)

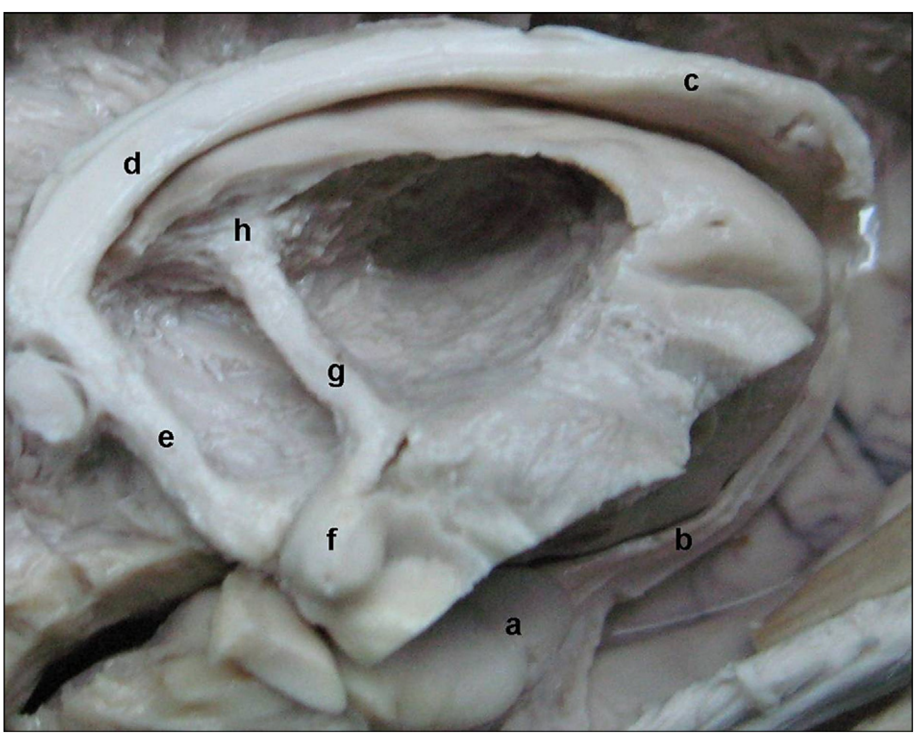

Fig. 5. Photograph showing the mamillary body and surrounding structures after the removal of the dentate gyrus: a, hippocampus; b, fimbria; c, crus of the fornix; d, body of the fornix; e, column of the fornix; f, mamillary body; g, mamillothalamic tract; h, anterior nucleus of the thalamus. (This figure is available in colour at www.sciencedirect.com.)

and forms an important relay center. Posteriorly, the parahippocampal gyrus is divided by the anterior calcarine sulcus into the isthmus of the cingulate gyrus superiorly which continues as the cingulate gyrus and the parahippocampal gyrus inferiorly which continues as the lingual gyrus[11] (Fig. 3).

The parahippocampal gyrus extends from the inferior surface medially towards the hippocampal fissure where it curves inwards to form the hippocampus, which in turn again curves inwards to form the dentate gyrus. The portion of the parahippocampal gyrus at the edge of the hippocampal fissure is known as the subiculum

Fig. 6. Photograph of the cingulum and surrounding structures after the anterior half of the corpus callosum had been cut and removed: a, cingulum; b, fibers of the cingulum entering into the parietal cortex; c, corpus callosum; d, head of caudate nucleus; e, body of the fornix; f, columns of the fornix; g, mamillary body; h, mamillothalamic tract; i, anterior nucleus of the thalamus; j, radiation of the cingulum; k, paraolfactory gyrus; l, paraterminal gyrus. (This figure is available in colour at www.sciencedirect.com.)

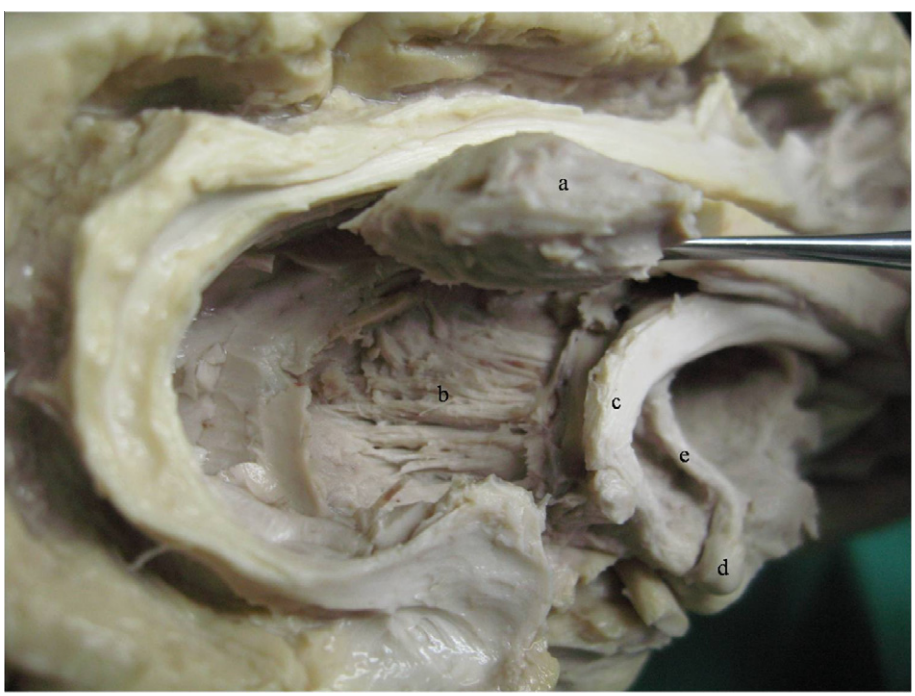

Fig. 7. Photograph of the anterior thalamic radiation after the caudate head had been lifted off in one piece: a, caudate head; b, anterior thalamic radiation; c, fornix; d, mamillary body; e, mamillothalamic tract. (This figure is available in colour at www.sciencedirect.com.)

and the area between the subiculum and the parahippocampal gyrus is known as the presubiculum.[9]

3.2. Hippocampus

The hippocampus (Greek meaning "seahorse") is where the Papez circuit begins and ends. It rests on the subiculum (Latin meaning "support") which forms the superior surface of the parahippocampal gyrus. The hippocampus is separated from the parahippocampal gyrus and the subiculum by the hippocampal fissure. Embryologically, the hippocampal formation is laid down along the hippocampal fissure. This fissure lies above and parallel to the choroidal fissure. As the temporal lobe develops, both these fissures are carried downwards and forwards to form a C-shaped

Fig. 8. Photograph of the anterior thalamic radiation projecting to the cingulum after the caudate head had been removed in one piece. Fibers forming the cingulum can also be seen radiating to the frontal cortex: a, anterior thalamic radiation; b, cingulum; c, fibers from the cingulum entering the frontal cortex; d, cut end of the corpus callosum; e, body of fornix; f, crus of fornix; g, anterior commisure; h, mamillary body; i, mamillothalamic tract; j, anterior nucleus of thalamus. (This figure is available in colour at www.sciencedirect.com.)

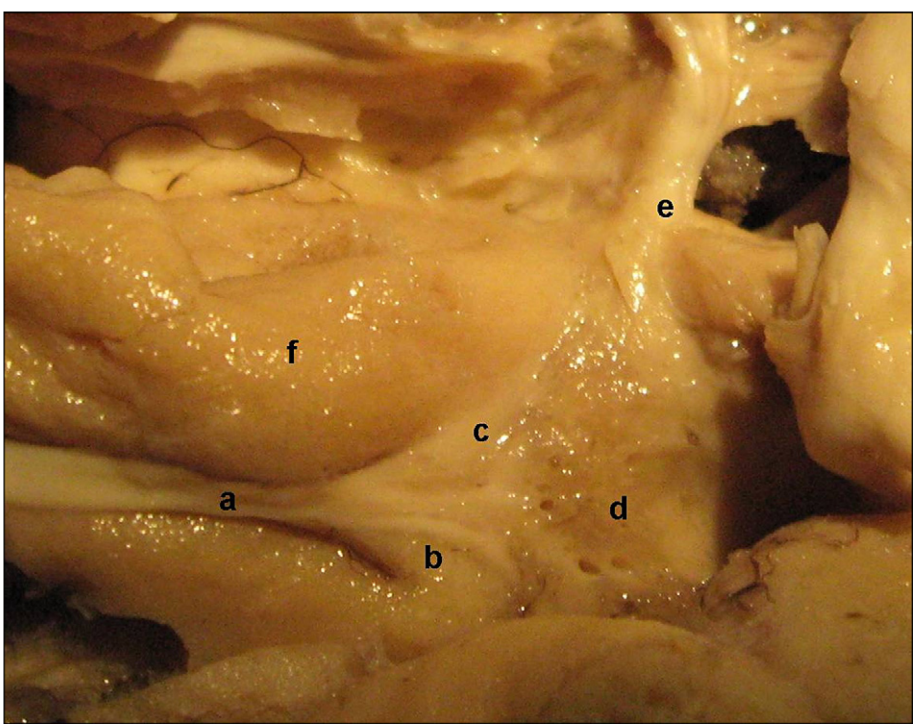

Fig. 9. Photograph of the inferior surface of the brain showing the basal forebrain region: a, olfactory tract; b, lateral olfactory stria; c, medial olfactory stria; d, anterior perforated substance; e, anterior commissure; f, gyrus rectus. (This figure is available in colour at www.sciencedirect.com.)

configuration.[9] The hippocampal formation does not develop to the same extent across the whole length of the hippocampal fissure. The dorsal part of the fissure is invaded by fibers of the corpus callosum and the hippocampal formation in this portion becomes a vestigeal band – the indusium griseum.[9,12] The inferior portion of the hippocampal fissure differentiates into the hippocampal formation which consists of the hippocampus proper, the dentate gyrus and the subiculum. The hippocampal formation forms the medial part of the floor of the temporal horn. From the hippocampus, fibers form a band known as the alveus (Latin meaning trough or hollow) that is located on its dome. It continues as the fimbria. Lateral to the fimbria and separated from it by the fimbrio-dentate sulcus, lies the dentate gyrus. When viewed from the medial aspect, the dentate gyrus is visualized as a thin band of cortex with

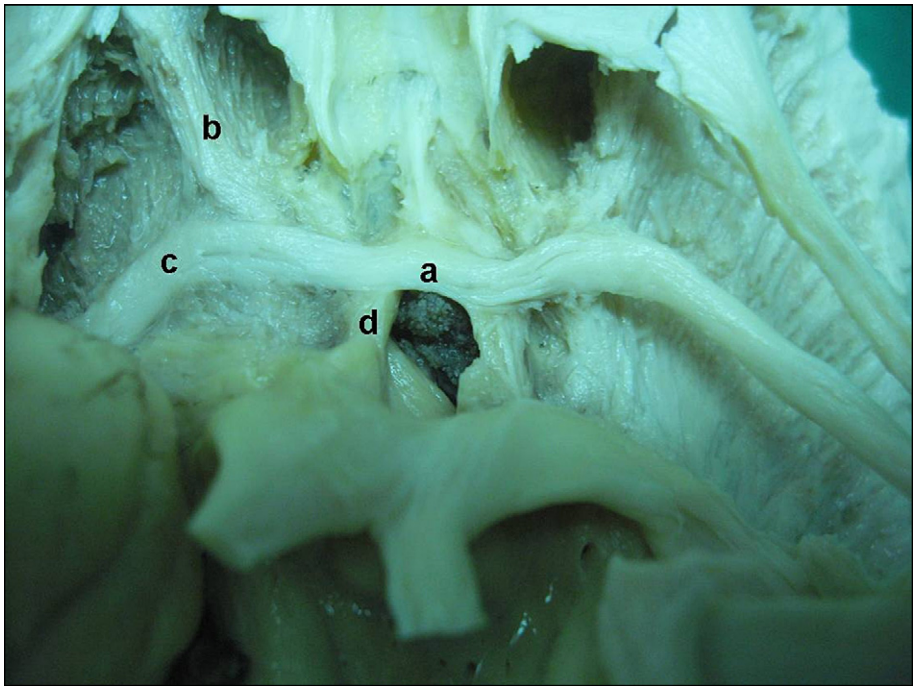

Fig. 10. Photograph showing the inferior surface of the basal forebrain after deeper dissection: a, anterior commissure; b, anterior portion of anterior commissure; c, posterior portion of anterior commissure; d, diagonal band of Broca. (This figure is available in colour at www.sciencedirect.com.)

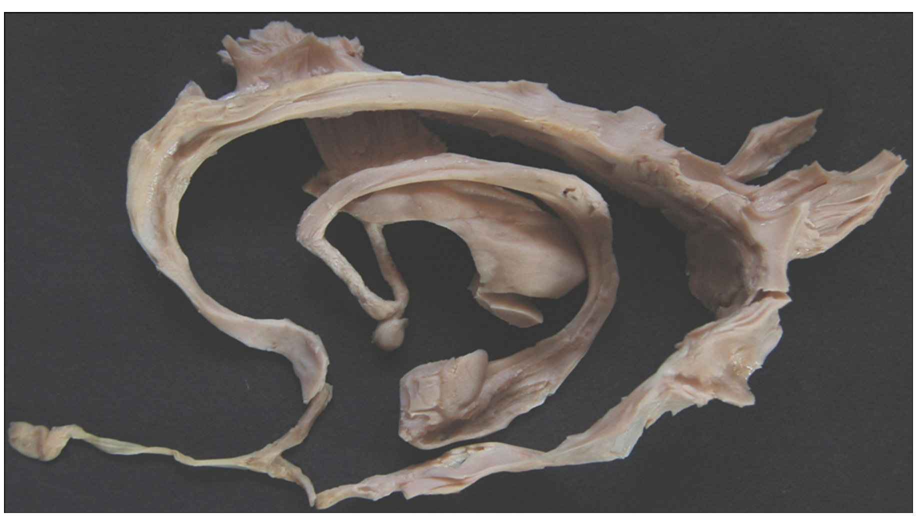

Fig. 11. Photograph of a reconstructed model showing the various connections of the limbic system. (This figure is available in colour at www.sciencedirect.com.)

a toothed appearance that lies between the fimbria above and the hippocampal fissure below (Fig. 4). The fimbria and the dentate gyrus run together posteriory till the splenium. Here, the dentate gyrus loses its denticulations and becomes the fasciolar gyrus which then runs superiorly over the corpus callosum. On the superior surface of the corpus callosum, the fasciolar gyrus becomes a thin lamina of gray matter, namely the indusium griseum, also known as the supracallosal gyrus.[9,12] Running within the indusium griseum are two bands of myelinated fibers, the medial and lateral longitudinal striae of Lancisii (Fig. 2). The indusium griseum and the longitudinal striae course over the entire corpus callosum and terminate in the paraterminal gyrus. The paraterminal gyrus then continues as the diagonal band of Broca.

3.3. Fornix

The fornix constitutes the main efferent pathway from the hippocampus, though it also carries a few afferent fibers. The fornix is composed of axons from the subiculum and the pyramidal cells of the hippocampus. The fornix begins as the alveus and the fimbria. The fimbria then forms the crus of the fornix (Latin meaning "vault or arch") which curve superolaterally over the pulvinar of the thalamus (Figs 4 and 5). Further anteriorly, the two crura meet in the midline to form the body of the fornix. The two crura of the fornices are connected by the hippocampal commissure or psalterium. Information is transmitted from one hemisphere to the other through this pathway. The body of the fornix runs forward to the anterior end of the thalamus, where the fibers of the two sides again separate and arch downwards in front of the intraventricular foramen as the columns of the fornix. The fibers of the fornix on approaching the anterior commisure divide into a pre commissural and a post commissural portion. Most of the fibers form the post commissural portion.[9,13] These fibers arise mainly from the subiculum and terminate into the mammillary body. These fibers reach the mammillary body and en route also give fibers to the lateral and anterior nucleus of the thalamus and to the lateral septal nuclei. Thus, the anterior nucleus of the thalamus receives fibers form the mamillothalamic tract and also recieves direct fibers from the post-commissural fornix. A few fibers pass ventral to the anterior commissure as the pre-commissural fornix. These fibers essentially originate mainly from the pyramidal cells of the hippocampus. Their input is principally to the septal nuclei, the lateral pre-optic area, the anterior part of the hypothalamus and the nucleus of the diagonal band.[9] The pre-commisural fibers form a small compact bundle that cannot be detected grossly. The post commissural fornix terminates into the medial mammillary nucleus. Fibers then arise from here and ascend upwards to the anterior nucleus of the thalamus forming the mamillothalamic tract of Vicq d'Azyr. Near its origin, the mamillothalamic tract gives rise to another smaller bundle known as the mamillotegmental tract (Fig. 3) which terminates according to many authors into the tegmental nucleus of Gudden.[5,14,15] From the anterior nucleus of the thalamus fibers radiate upward and mingle with the fibers of the anterior limb of the internal capsule to reach the cingulum (Latin meaning "girdle") and the cingulate gyrus (Figs 7 and 8).

3.4. Cingulum

The cingulum is an association bundle which runs superior and parallel to the corpus callosum. Its fibers terminate anteriorly below the rostrum of the corpus callosum in the subcallosal gyrus. Posteriorly the cingulum narrows above the splenium, where it forms the isthumus of the cingulum and this continues below as the radiation of the cingulum to end in the anterior parahippocampal region adjacent to the hippocampus (Fig. 6).

3.5. Dentate gyrus

The dentate gyrus (Fig. 4) receives input mainly from the entorhinal area. The input is mainly by means of two pathways, the perforant path and the alvear path. The fibers of the perforant path originate in the lateral part of the entorhinal cortex, traverse through the subiculum and terminate in the dentate gyrus. The alvear path originates in the medial part of the entorhinal cortex and enters the hippocampus from the ventricular surface after traversing the alveus.[9]

3.6. Amygdala

The *amygdala* (Greek meaning "almond-like") lies entirely within the confines of the uncus. The amygdala gives rise to two major pathways, the stria terminalis and the ventral amygdalofugal pathway.[9] The stria terminalis is a C-shaped structure which exits from the ventromedial portion of the amygdala and arches along the entire medial border of the caudate nucleus near its junction with the thalamus, around the lateral ventricle. These fibers terminate in the bed nuclei of the stria terminalis which lies lateral to the columns of the fornix and dorsal to the anterior commissure. Some fibers also terminate in the hypothalamus and some join the medial forebrain bundle.[9]

The bed nucleus of the stria terminalis, runs along with the stria terminalis and is largest rostrally. It receives input from all nuclei of the amygdala. The bed nucleus of the stria terminalis has widespread connections to the rest of the limbic system and therefore provides an important route by which the amygdala can affect structures beyond the connections of the stria terminalis itself. The ventral amygdalofugal pathway courses medially from the amygdala to the basal nucleus of Meynert and the dorsal medial nucleus of the thalamus. It is a diffuse, myelinated bundle lying ventral to the globus pallidus (medial pole). It courses medially and rostrally beneath the lentiform nucleus, passes through the substantia innominata to reach the hypothalamus, septal areas, lateral preoptic area and the nucleus of the diagonal band of Broca. Some fibers proceed via the inferior thalamic peduncle to reach the dorsomedial nucleus of the thalamus.[9]

3.7. Basal forebrain

The mediobasal frontal cortical area of each cerebral hemisphere, composed of the paraterminal gyrus and the paraolfactory gyri, is also considered a limbic cortical area.[12] It extends from the olfactory tubercle rostrally to the hypothalamus caudally. It lies over the anterior perforated substance and does not have any definite boundaries. The basal forebrain includes the septal area, the olfactory tubercle, parts of the amygdala and the substantia innominata (basal nucleus). The lateral olfactory stria and gyrus pass along the lateral margin of the anterior perforated substance to reach the piriform region. These fibers terminate in the piriform cortex and in the corticomedial part of the amygdaloid nuclear complex.

The medial olfactory stria becomes continuous with the subcallosal and the paraterminal gyrus (Figs 9 and 10). The subcallosal area and the paraterminal gyrus constitute the septal area, beneath which are the septal nuclei. The septal region is situated on the medial surface of the cerebral hemisphere, immediately facing the anterior commissure. The medial septal nucleus becomes continuous with the nucleus and tract of the diagonal band of Broca, which then connects with the hippocampal formation. The septal nuclei receive afferents principally from the hippocampus and subiculum of the parahippocampal gyrus via the indusium griseum as well as from the precommissural fornix. The efferents of the septal nuclei project to the area surrounding the hippocampus via the fornix itself, to the hypothalamus and midbrain tegementum via the medial forebrain bundle, to the habenula via the stria medullaris thalami, which in turn projects to the mesencephalon via the fasciolus retroflexus.[9,12] Functionally, the septal nuclei are responsible for connecting limbic structures with the hypothalamus and the brainstem, principally via the hippocampal formation.

3.8. Anterior commisure (Figs 10 and 12)

The anterior commissure crosses the midline anterior to the columns of the fornix. The entire extent of the anterior commissure resembles a horizontally placed bow. It runs in a canal of gray matter (canal of Gratiolet) parallel and deep to the uncinate fasciculus and the occipitofrontal fasciculus. The average distance of the anterior commissure from the temporal pole was 18 mm (16–20 mm) and the average distance of the uncinate fasciculus from the anterior commissure was 6 mm (3–8 mm) Laterally the anterior commissure splits into two, an anterior or olfactory portion and a posterior or temporal portion (Fig. 12). The anterior portion of the commissure consists of fibers arising from the anterior olfactory nucleus, which cross to the opposite side and end in the anterior olfactory nucleus on the contralateral side. The posterior or the temporal portion of the anterior commissure forms the major bulk and passes laterally, deep to the lentiform nucleus, to end in the middle temporal gyrus. Some fibers enter the external capsule laterally and some fibers course posteriorly

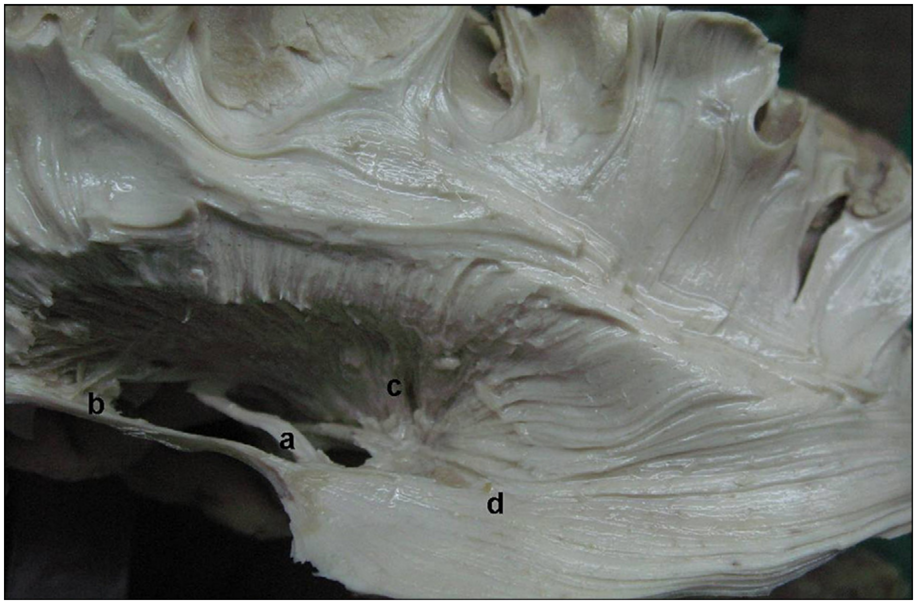

Fig. 12. Photograph showing the lateral view of the cerebral hemisphere. The insular region has been dissected to show the course of the posterior portion of the anterior commissure: a, anterior commissure; b, limen insulae; c, internal capsule; d, sagittal stratum and optic radiations. (This figure is available in colour at www.sciencedirect.com.)

as part of the sagittal stratum (Fig. 12). The anterior commissure has a role in the transfer of visual, olfactory and auditory information between the temporal lobes.

3.9. Limbic connections between the telencephalon, diencephalon and mesencephalon

The stria medullaris is a fiber bundle that runs from the septal region to the habenular nuclei. The impulses from the habenular nuclei are then conveyed via the fasciculus retroflexus to the midbrain.[16]

The medial forebrain bundle projects to the midbrain tegmentum, after originating from the septal and lateral preoptic region. It also carries ascending fibers from the midbrain. Ascending fibers to the mamillary body run in the mamillary peduncle. They arise from the dorsal and ventral nuclei of Gudden and traverse to the mamillary body. Some fibers continue rostrally to the lateral hypothalamic regions, medial septal nuclei and preoptic areas via the medial forebrain bundle.[16]

4. Clinical Implications

Diffusion tensor imaging (DTI) and diffusion spectrum imaging (DSI) have been used to study the components of the Papez circuit non-invasively.[17,18] Granziera et al. used DSI and showed the three major fiber bundles of the Papez circuit and some sparse connections between the thalamus and cingulate cortex.[17] The connections between the thalamus and the cingulate gyrus are clearly visualized in our anatomical study. Fiber dissection techniques provide the neurosurgeon with a three-dimensional spatial orientation of the brain. But with fiber dissection techniques, one fiber tract needs to be destroyed or displaced to study the anatomy of the adjoining or deeper fiber bundle. This limitation of fiber dissection can be overcome with DTI studies where normal anatomy as well as abnormal displacements of the fibers can be visualized. For an accurate DTI study, knowledge of anatomy is essential for accurate voxel placing. Hence, both the methods are complimentary and can be used to better understand the anatomy. DTI studies have also shown altered diffusion patterns in the hippocampus, cingulum and fornix in patients with mesial temporal lobe epilepsy.[18] DTI studies have reported decreased fractional anisotropy of the cingulum bundle in patients suffering from schizophrenia and Alzheimer's disease.[18] Thus the study of the structure of the Papez circuit by DTI can be used as a diagnostic and monitoring tool in patients with neurological disorders.

Limbic systems are affected in lesions of the medial and basal surfaces of the cerebral hemispheres and the diencephalon. Some of the fiber systems are traversed in approaching lesions of the lateral and third ventricle. Lesions originating from the medial frontal, parietal and occipital lobes, from parts of the cingulate gyrus, corpus callosal lesions and lateral ventricular tumors can be approached via a transcortical and an interhemispheric approach. The merits and deficiencies of both the approaches have been discussed extensively. Along with injuries to cortical areas, trans-cortical approaches disrupt the white matter tracts in the region. The white matter tracts at risk are the cingulum and the connections between the cingulum and the frontal, parietal and occipital cortices. The anatomy of the hippocampus, amygdala and its relations are important to know while performing epilepsy surgery. A transforaminal transchoroidal approach to the third ventricle avoids damage to the fornix. A thorough knowledge of the anatomy and physiology of the limbic system can aid the neurosurgeon while approaching and operating in this region.

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