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Measurement of Corpus Callosum in Sudanese Population Using MRI

توصيف الجسم الثفني لدى السودانيين باستخدام التصوير بالرنين المغناطيسي

A thesis submitted in Partial fulfillment of the requirement of the degree of M. Sc. In Diagnostic Radiologic Technology

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Chapter one

Introduction

1-1. INTRODUCTION

Corpus callosum (CC) is the main fiber tract connecting the cortical and subcortical regions of the right and left hemispheres and plays an essential role in the integration of information between the two hemispheres (Gupta ,et al 2008).Position and size of the corpus callosum is well appreciated in median sections. The anterior end is called "*the genu",* the median region *"the corpus"* and the posterior region *"the splenium"*. Nerve fibres of the corpus callosum radiate into the white area of each hemisphere dispersing to the various regions of the cerebral cortex (William , et al 1989).

Regarding differences in the size of organs in humans including (CC) according to race/ethnicity in various parts of the world, (CC) dimensions, morphology and sex-related differences have been of interest to researchers (mourgela , et al 2007) .By using magnetic resonance imaging (MRI), the dimensions of (CC) including size, diameters, age morphology and also gender-related differences have been determined in several studies (Peterson, et al Permudez et al , 2001).Most of the studies of (CC) measurements have been performed on Caucasian samples (Sulivan , et al ; Witelson et al 2001, 1989)and there are very few studies of (CC) in the Indian population(Banka et al 1996; Suganthy et al , 2003) however and to the best of our knowledge, no study was conducted in the open literature regarding Sudanese population for Corpus callosum measurements. Moreover greater numbers of studies are carried out on MRI scans.

Morphological deviations from normal may serve as an index for the presence and progress of various neuropathological conditions The present study was conducted using MRI scans to get inclusive data regarding (CC) in normal adult Sudanese population and to present the results of callosal anatomy in association to gender and age-related differences as well as to reveal the help of

magnetic resonance imaging (MRI) in demonstrating the neuroanatomy of the corpus callosum. This will give normative data on (CC) morphology in the population under study and thus establish reference values for studying age, gender and racial differences.

1.2 Statement of the problems:

Agenesis of the corpus callosum (ACC) is an anomaly that may occur in isolation or in association with other central nervous system (CNS) or systemic malformations. Because the corpus callosum may be partially or completely absent. The term digenesis has also been used to describe the spectrum of callosal anomalies. The normal appearance of the corpus callosum. Along with the appearance on magnetic resonance imaging (MRI) is important, to our knowledge no measurement had been done for normal corpus callosum for sudanese population.

1.3 Objective of the study:

1.3.1 General objectives.

Measurement of corpus callosum in Sudanese Population Using MRI.

1.3.2 Specific objectives :

- To measure the corpus callosum length, genu, splenium, CCI.
- To correlate the measurement with age and gender..
- To correlate the measurement with subjects age and gender.
- The measure the head diameter (brain AP, sagtal , transfer)

CHAPTER TWO

Literature Review

2-1 Anatomy of the brain

2-1-1 Overview

Nothing in the world can compare with the human brain. This mysterious three-pound organ controls all necessary functions of the body, receives and interprets information from the outside world, and embodies the essence of the mind and soul. Intelligence, creativity, emotion, and memories are a few of the many things governed by the brain.

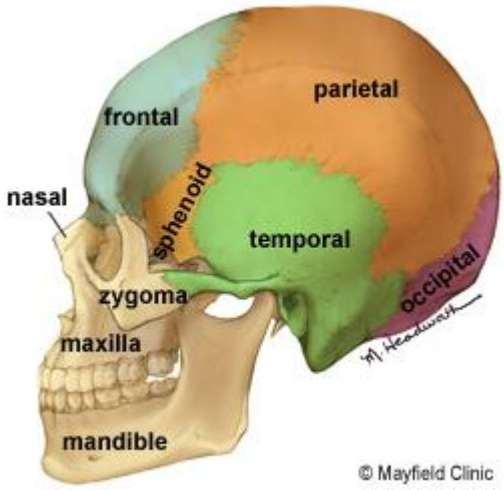
The brain receives information through our five senses: sight, smell, touch, taste, and hearing; often many at one time. It assembles the messages in a way that has meaning for us, and can store that information in our memory. The brain controls our thoughts, memory and speech, movement of the arms and legs, and the function of many organs within our body. It also determines how we respond to stressful situations (such as taking a test, losing a job, or suffering an illness) by regulating our heart and breathing rate.

2-1-2 Nervous system

The nervous system is divided into central and peripheral systems. The central nervous system (CNS) is composed of the brain and spinal cord. The peripheral nervous system (PNS) is composed of spinal nerves that branch from the spinal cord and cranial nerves that branch from the brain. The PNS includes the autonomic nervous system, which controls vital functions such as breathing, digestion, heart rate, and secretion of hormones.

2-1-3 Skull

The purpose of the bony skull is to protect the brain from injury. The skull is formed from 8 bones that fuse together along suture lines. These bones include the frontal, parietal (2), temporal (2), sphenoid, occipital and ethmoid (see the Fig. below). The face is formed from 14 paired bones including the maxilla , zygoma, nasal, palatine, lacrimal, inferior nasal conchae, mandible, and vomer.



Fig(2-1) Eight bones form the skull and fourteen bones form the face.

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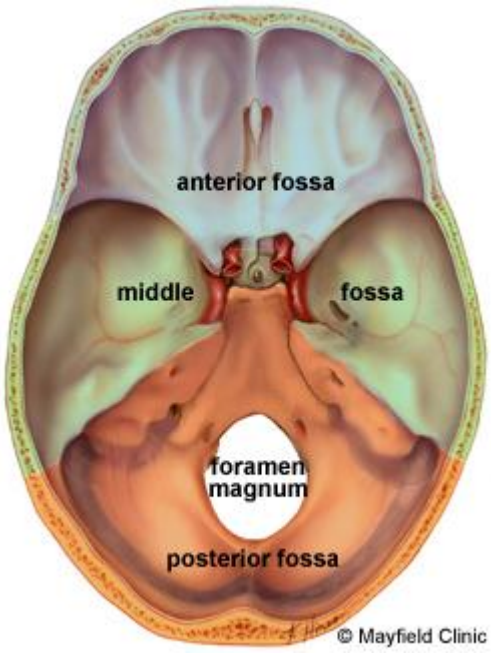
Inside the skull are three distinct areas: anterior fossa, middle fossa, and posterior fossa (see the Fig. below). Doctors sometimes refer to a tumor's location by these terms, e.g., middle fossa meningioma.



Fig(2-2) :**The inside of the skull is divided into three areas called the anterior, middle, and posterior fossae.**

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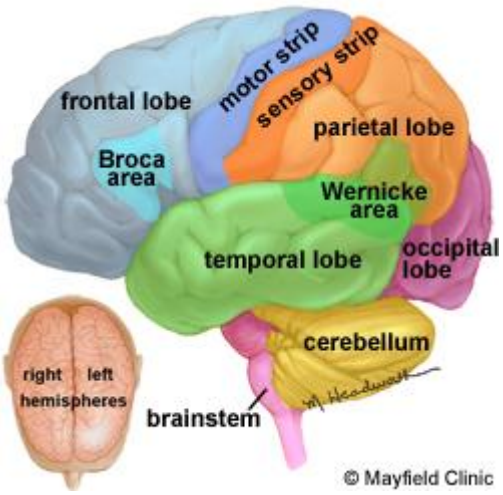
Similar to cables coming out the back of a computer, all the arteries, veins and nerves exit the base of the skull through holes, called foramina. The big hole in the middle (foramen magnum) is where the spinal cord exits.

2-1-4 Brain

The brain is composed of the cerebrum, cerebellum, and brainstem (see the Fig. below).



Fig(2-3) : The brain is composed of three parts: the brainstem, cerebellum, and cerebrum.

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The cerebrum is divided into four lobes: frontal, parietal, temporal, and occipital.

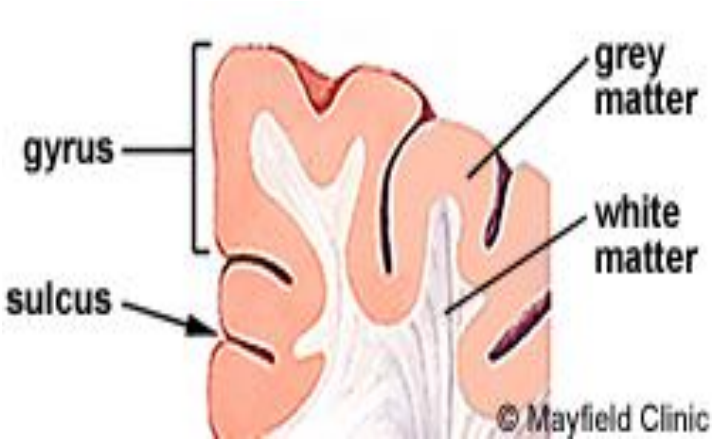
The **cerebrum** is the largest part of the brain and is composed of right and left hemispheres. It performs higher functions like interpreting touch, vision and hearing, as well as speech, reasoning, emotions, learning, and fine control of movement.

The **cerebellum** is located under the cerebrum. Its function is to coordinate muscle movements, maintain posture, and balance.

The **brainstem** includes the midbrain, Pons, and medulla. It acts as a relay center connecting the cerebrum and cerebellum to the spinal cord. It performs many automatic functions such as breathing, heart rate, body temperature, wake

and sleep cycles, digestion, sneezing, coughing, vomiting, and swallowing. Ten of the twelve cranial nerves originate in the brainstem.

The surface of the cerebrum has a folded appearance called the cortex. The cortex contains about 70% of the 100 billion nerve cells. The nerve cell bodies color the cortex grey-brown giving it its name – gray matter (see the Fig. below). Beneath the cortex are long connecting fibers between neurons, called axons, which make up the white matter.



Fig(2-4) : The surface of the cerebrum is called the cortex. The cortex contains neurons (grey matter), which are interconnected to other brain areas by axons (white matter). The cortex has a folded appearance. A fold is called a gyrus and the groove between is a sulcus.

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The folding of the cortex increases the brain's surface area allowing more neurons to fit inside the skull and enabling higher functions. Each fold is called a gyrus, and each groove between folds is called a sulcus. There are names for the folds and grooves that help define specific brain regions. (Williams Pl; Warwiek ,1989)

2-1-5 Right brain – left brain

The right and left hemispheres of the brain are joined by a bundle of fibers called the corpus callosum that delivers messages from one side to the other. Each hemisphere controls the opposite side of the body. If a brain tumor is

located on the right side of the brain, your left arm or leg may be weak or paralyzed.

Not all functions of the hemispheres are shared. In general, the left hemisphere controls speech, comprehension, arithmetic, and writing. The right hemisphere controls creativity, spatial ability, artistic, and musical skills. The left hemisphere is dominant in hand use and language in about 92% of people.

2-1-6 Lobes of the brain

The cerebral hemispheres have distinct fissures, which divide the brain into lobes. Each hemisphere has 4 lobes: frontal, temporal, parietal, and occipital (see the Fig below). Each lobe may be divided, once again, into areas that serve very specific functions. It's important to understand that each lobe of the brain does not function alone. There are very complex relationships between the lobes of the brain and between the right and left hemispheres.

2-1-6-1 Frontal lobe; the main functions are:

a- Personality, behavior, emotions.

b- Judgment, planning, problem solving.

c- Speech: speaking and writing (Broca's area).

d- Body movement (motor strip).

e- Intelligence, concentration, self awareness.

2-1-6-2 Parietal lobe

a- Interprets language, words

b- Sense of touch, pain, temperature (sensory strip)

c- Interprets signals from vision, hearing, motor, sensory and memory

d- Spatial and visual perception

2-1-6-3 Occipital lobe

- Interprets vision (color, light, movement)

2-1-6-4 Temporal lobe

a- Understanding language (Wernicke's area).

b- Memory.

c- Hearing.

d- Sequencing and organization.

Messages within the brain are carried along pathways. Messages can travel from one gyrus to another, from one lobe to another, from one side of the brain to the other, and to structures found deep in the brain (e.g. thalamus, hypothalamus).

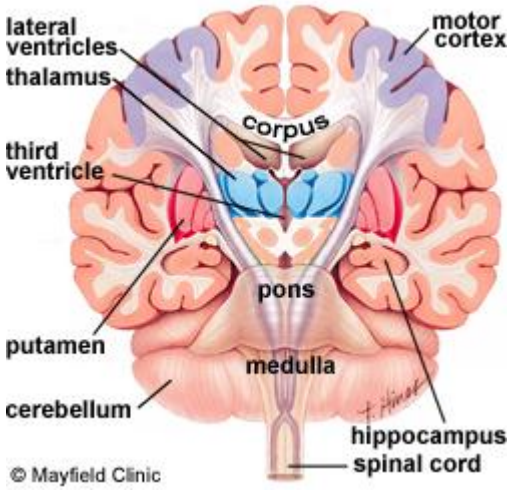
2-1-7 Deep structures:

2-1-7-1 Hypothalamus - is located in the floor of the third ventricle and is the master control of the autonomic system. It plays a role in controlling behaviors such as hunger, thirst, sleep, and sexual response. It also regulates body temperature, blood pressure, emotions, and secretion of hormones.

2-1-7-2 Pituitary gland - lies in a small pocket of bone at the skull base called the sella turcica. The pituitary gland is connected to the hypothalamus of the brain by the pituitary stalk. Known as the "master gland," it controls other endocrine glands in the body. It secretes hormones that control sexual development, promote bone and muscle growth, respond to stress, and fight disease.

2-1-7-3 Pineal gland - is located behind the third ventricle. It helps regulate the body's internal clock and circadian rhythms by secreting melatonin. It has some role in sexual development.

2-1-7-4 Thalamus - serves as a relay station for almost all information that comes and goes to the cortex (see the Fig. below). It plays a role in pain sensation, attention, alertness and memory.



Fig(2-5) **Coronal cross-section showing the basal ganglia.**

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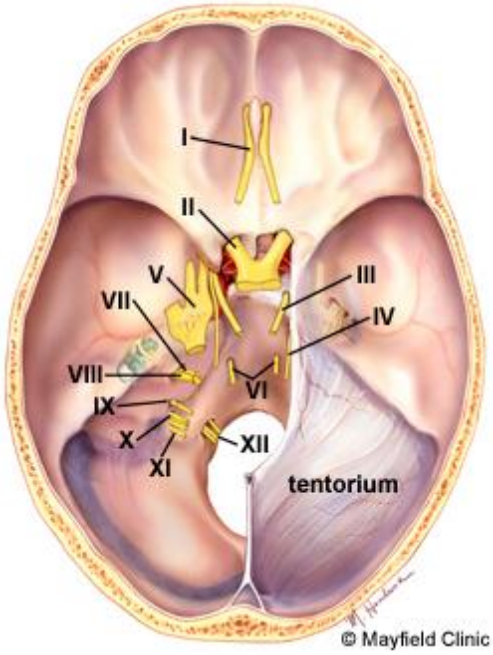
2-1-7-5 Basal ganglia - includes the caudate, putamen and globus pallidus. These nuclei work with the cerebellum to coordinate fine motions, such as fingertip movements.

2-1-7-6 Limbic system - is the center of our emotions, learning, and memory. Included in this system are the cingulate gyri, hypothalamus, amygdala (emotional reactions) and hippocampus (memory).

2-1-7-7 Cranial nerves

The brain communicates with the body through the spinal cord and twelve pairs of cranial nerves (see the Fig. below). Ten of the twelve pairs of cranial nerves that control hearing, eye movement, facial sensations, taste, swallowing and movement of the face, neck, shoulder and tongue muscles originate in the brainstem. The cranial nerves for smell and vision originate in the cerebrum.



Fig(2-6) : The Roman numeral, name, and main function of the twelve cranial nerves.

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Table (2.1) : The Roman numeral, name, and main function of the twelve cranial nerves

Number	Name	Function
I	olfactory	Smell
II	Optic	Sight
III	oculomotor	moves eye, pupil
IV	trochlear	moves eye
V	trigeminal	face sensation
VI	abducens	moves eye
VII	Facial	moves face, salivate
VIII	vestibulocochlear	hearing, balance
IX	glossopharyngeal	taste, swallow
X	Vagus	heart rate, digestion
XI	accessory	moves head
XII	hypoglossal	moves tongue

2-1-8 Meninges

The brain and spinal cord are covered and protected by three layers of tissue called meninges. From the outermost layer inward they are: the dura mater, arachnoid mater, and pia mater.

The dura mater is a strong, thick membrane that closely lines the inside of the skull; its two layers, the periosteal and meningeal dura, are fused and separate only to form venous sinuses. The dura creates little folds or compartments. There are two special dural folds, the falx and the tentorium. The falx separates the right and left hemispheres of the brain and the tentorium separates the cerebrum from the cerebellum.

The arachnoid mater is a thin, web-like membrane that covers the entire brain. The arachnoid is made of elastic tissue. The space between the dura and arachnoid membranes is called the subdural space.

The pia mater hugs the surface of the brain following its folds and grooves. The pia mater has many blood vessels that reach deep into the brain. The space between the arachnoid and pia is called the subarachnoid space. It is here where the cerebrospinal fluid bathes and cushions the brain.

2-1-9 Ventricles and cerebrospinal fluid

The brain has hollow fluid-filled cavities called ventricles (see the Fig. below). Inside the ventricles is a ribbon-like structure called the choroid plexus that makes clear colorless cerebrospinal fluid (CSF). CSF flows within and around the brain and spinal cord to help cushion it from injury. This circulating fluid is constantly being absorbed and replenished.

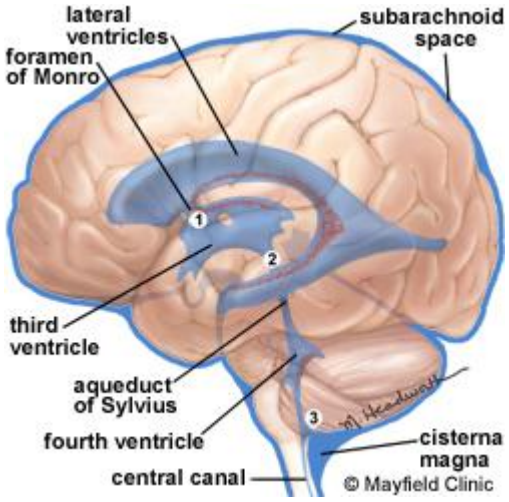

Fig (2-7) : **CSF is produced inside the ventricles deep within the brain. CSF fluid circulates inside the brain and spinal cord and then outside to the subarachnoid space. Common sites of obstruction: 1) foramen of Monro, 2) aqueduct of Sylvius, and 3) obex.**

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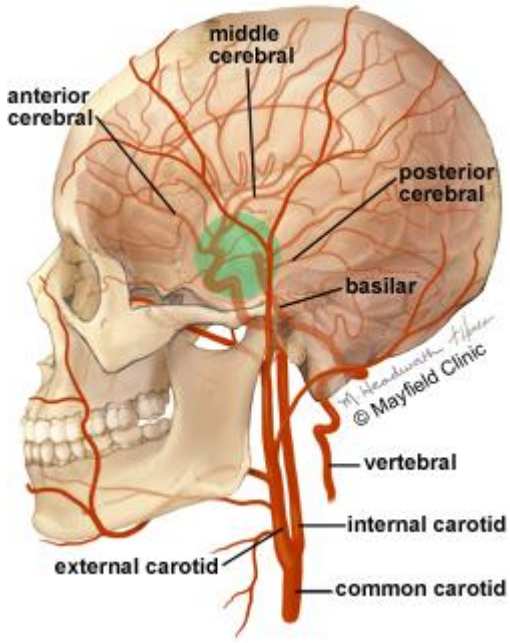
There are two ventricles deep within the cerebral hemispheres called the lateral ventricles. They both connect with the third ventricle through a separate opening called the foramen of Monro. The third ventricle connects with the fourth ventricle through a long narrow tube called the aqueduct of Sylvius. From the fourth ventricle, CSF flows into the subarachnoid space where it bathes and cushions the brain. CSF is recycled (or absorbed) by special structures in the superior sagittal sinus called arachnoid villi.

A balance is maintained between the amount of CSF that is absorbed and the amount that is produced. A disruption or blockage in the system can cause a buildup of CSF, which can cause enlargement of the ventricles (hydrocephalus) or cause a collection of fluid in the spinal cord (syringomyelia).

2-1-10 Blood supply

Blood is carried to the brain by two paired arteries, the internal carotid arteries and the vertebral arteries (see the Fig. below). The internal carotid arteries supply most of the cerebrum.



Fig(2-8):The common carotid artery courses up the neck and divides into the internal and external carotid arteries. The brain's anterior circulation is fed by the internal carotid arteries (ICA) and the posterior circulation is fed by the vertebral arteries (VA). The two systems connect at the Circle of Willis.

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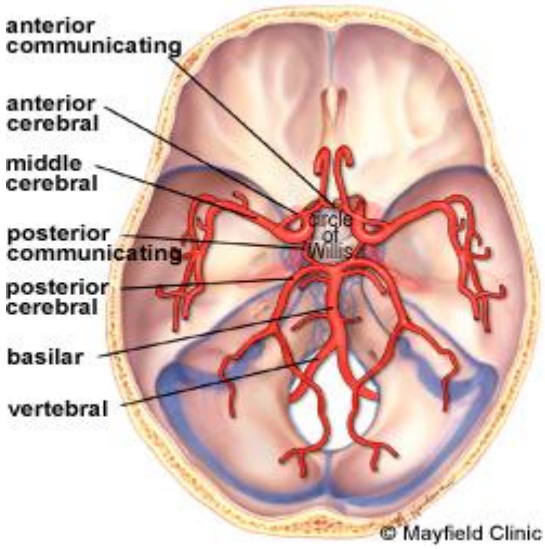
The vertebral arteries supply the cerebellum, brainstem, and the underside of the cerebrum. After passing through the skull, the right and left vertebral arteries join together to form the basilar artery. The basilar artery and the internal carotid arteries "communicate" with each other at the base of the brain called the Circle of Willis (see the Fig. below). The communication between the internal carotid and vertebral-basilar systems is an important safety feature of the brain. If one of the major vessels becomes blocked, it is possible for collateral blood flow to come across the Circle of Willis and prevent brain damage.



Fig(2-9): Top view of the Circle of Willis. The internal carotid and vertebral-basilar systems are joined by the anterior communicating and posterior communicating arteries.
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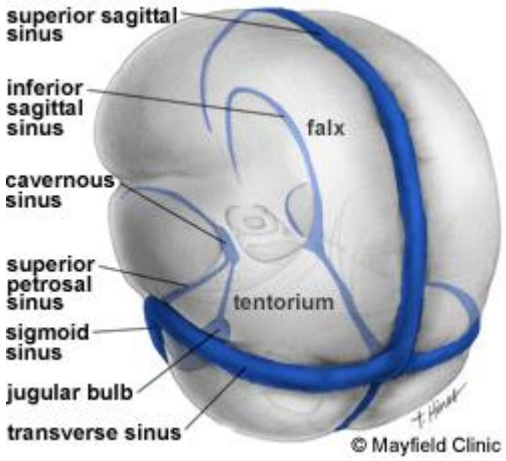
The venous circulation of the brain is very different than the rest of the body. Usually arteries and veins run together as they supply and drain specific areas of the body. So one would think there would be a pair of vertebral veins and internal carotid veins. However, this is not the case in the brain. The major vein collectors are integrated into the dura to form venous sinuses (see the Fig. below) - not to be confused with the air sinuses in the face and nasal region. The venous sinuses collect the blood from the brain and pass it to the internal jugular veins. The superior and inferior sagittal sinuses drain the cerebrum, the cavernous sinuses drains the anterior skull base. All sinuses eventually drain to the sigmoid sinuses, which exit the skull and form the jugular veins. These two jugular veins are essentially the only drainage of the brain.



Fig(2-10) : **Three quarter view of the dural covering of the brain depicts the two major dural folds, the falx and tentorium along with the venous sinuses.**

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2-1-11 Language

In general, the left hemisphere of the brain is responsible for language and speech and is called the "dominant" hemisphere. The right hemisphere plays a large part in interpreting visual information and spatial processing. In about one third of individuals who are left-handed, speech function may be located on the right side of the brain. Left-handed individuals may need special testing to determine if their speech center is on the left or right side prior to any surgery in that area.

Aphasia is a disturbance of language affecting production, comprehension, reading or writing, due to brain injury – most commonly from stroke or trauma. The type of aphasia depends on the brain area affected.

Broca's area lies in the left frontal lobe (Fig 3). If this area is damaged, one may have difficulty moving the tongue or facial muscles to produce the sounds of speech. The individual can still read and understand spoken language but has difficulty in speaking and writing (i.e. forming letters and words, doesn't write within lines) – called Broca's aphasia.

Wernicke's area lies in the left temporal lobe (Fig 3). Damage to this area causes Wernicke's aphasia. The individual may speak in long sentences that have no meaning, add unnecessary words, and even create new words. They can make speech sounds, however they have difficulty understanding speech and are therefore unaware of their mistakes.

2-1-12 Memory

Memory is a complex process that includes three phases: encoding (deciding what information is important), storing, and recalling. Different areas of the brain are involved in memory depending on the type of memory.

Short-term memory, also called working memory, occurs in the prefrontal cortex. It stores information for about one minute and its capacity is limited to about 7 items. For example, it enables you to dial a phone number someone just told you. It also intervenes during reading, to memorize the sentence you have just read, so that the next one makes sense.

Long-term memory is processed in the hippocampus of the temporal lobe and is activated when you want to memorize something for a longer time. This memory has unlimited content and duration capacity. It contains personal memories as well as facts and figures.

Skill memory is processed in the cerebellum, which relays information to the basal ganglia. It stores automatic learned memories like tying a shoe, playing an instrument, or riding a bike.

2-1-13 Cells of the brain

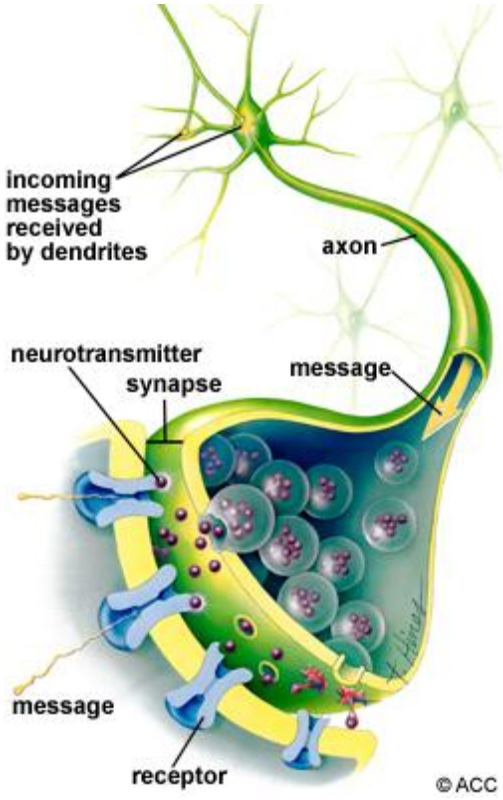
The brain is made up of two types of cells: nerve cells (neurons) and glia cells.

2-1-13-1 Nerve cells

There are many sizes and shapes of neurons, but all consist of a cell body, dendrites and an axon. The neuron conveys information through electrical and chemical signals. Try to picture electrical wiring in your home. An electrical circuit is made up of numerous wires connected in such a way that when a light

switch is turned on, a light bulb will beam. A neuron that is excited will transmit its energy to neurons within its vicinity.

Neurons transmit their energy, or "talk", to each other across a tiny gap called a synapse (see the Fig. below). A neuron has many arms called dendrites, which act like antennae picking up messages from other nerve cells. These messages are passed to the cell body, which determines if the message should be passed along. Important messages are passed to the end of the axon where sacs containing neurotransmitters open into the synapse. The neurotransmitter molecules cross the synapse and fit into special receptors on the receiving nerve cell, which stimulates that cell to pass on the message.



Fig(2-11): Nerve cells consist of a cell body, dendrites and axon. Neurons communicate with each other by exchanging neurotransmitters across a tiny gap called a synapse.

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2-1-13-2 Glia cells

Glias (Greek word meaning glue) are the cells of the brain that provide neurons with nourishment, protection, and structural support. There is about 10 to 50 times more glia than nerve cells and is the most common type of cells involved in brain tumors.

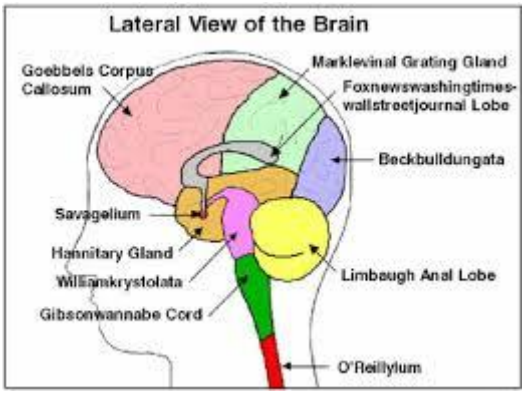
Astroglia or astrocytes transport nutrients to neurons, hold neurons in place, digest parts of dead neurons, and regulate the blood brain barrier.

Oligodendroglia cells provide insulation (myelin) to neurons.

Ependymal cells line the ventricles and secrete cerebrospinal fluid (CSF).

Microglia digests dead neurons and pathogens.

Image. Huffington post/2007-12-17 lolbrain.jpg



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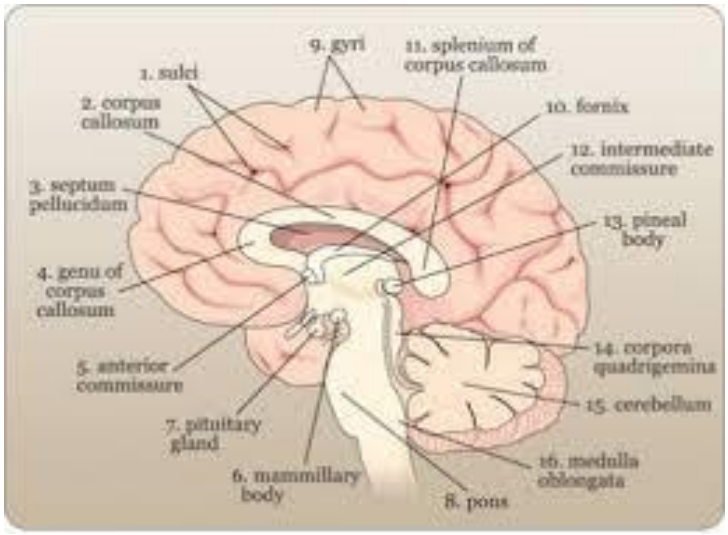

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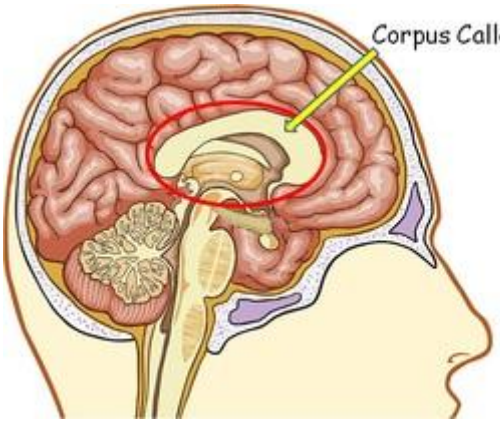


C

Fig(2-12) :The corpus callosum:

http://brainmadesimple.com/uploads/7/8/8/5/7885523/_9017293.jpg

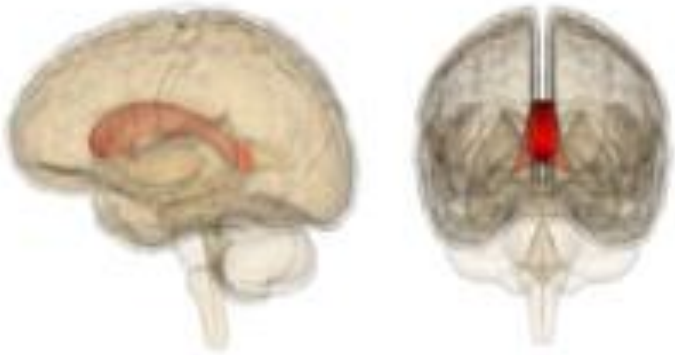


Fig (2-13) : Corpus callosum with Anatomography

https://en.wikipedia.org/wiki/corpus-collosum#/media /file:corpus-collosum.png

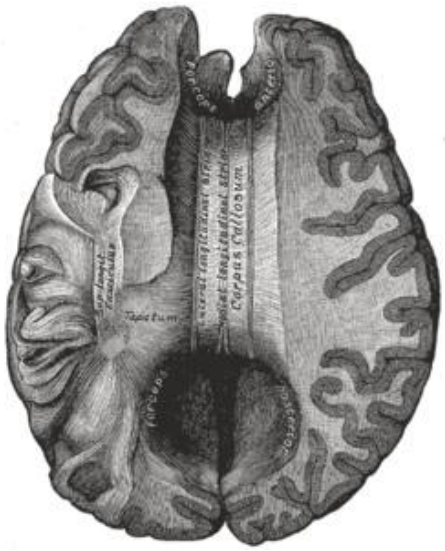
2-2 Anatomy of Corpus callosum

The **corpus callosum** (Latin for "tough body"), also known as the callosal commissure, is a wide, flat bundle of neural fibers beneath the cortex in the eutherian brain at the longitudinal fissure. It connects the left and right cerebral hemispheres and facilitates interhemispheric communication. It is the largest white matter structure in the brain, consisting of 200–250 million contralateral axonal projections.

Corpus callosum is a bundle of nerve fibers in the longitudinal fissure of the brain that enables corresponding regions of the left and right cerebral hemispheres to communicate. The axons and dendrites of the neurons in the corpus callosum synapse with cortical neurons on symmetrically related points of the hemispheres. Thus, electrical stimulation of a point on one hemisphere usually gives rise to a response on a symmetrically related point on the other, by virtue of these callosal connections. The neurons in the corpus callosum also are insulated by a myelin sheath, which facilitates the rapid conduction of electrical impulses between the hemispheres. (Gouliamos A,2007)

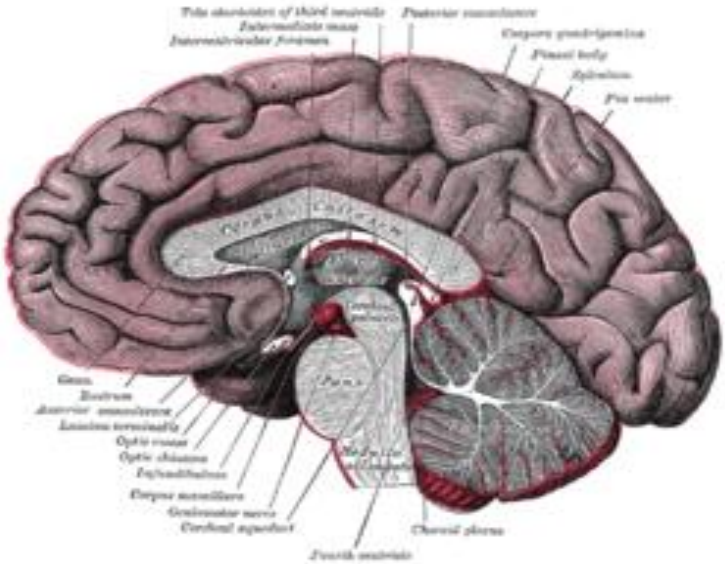
Diseases affecting the corpus callosum include Marchiafava-Bignami disease, which is characterized by progressive demyelination of the neurons of the corpus callosum. In addition, agenesis (imperfect development) of the corpus callosum can cause intellectual disability and seizures. A reduced amount of tissue in the corpus callosum also has been associated with attention-deficit/hyperactivity disorder. (Warwiek, R. ,1989)

The corpus callosum has played an important role in the elucidation of functions specific to each of the cerebral hemispheres. For example, studies of individuals being treated for epilepsy in which the corpus callosum has been severed, allowing the two hemispheres to function largely independently, have revealed that the right hemisphere has more language competence than was thought.



Fig(2-14): Corpus callosum from above. (Anterior portion is at the top of the image.)

https://en.wikipedia.org/wiki/corpus-collosum#/media /file:Gray733.png

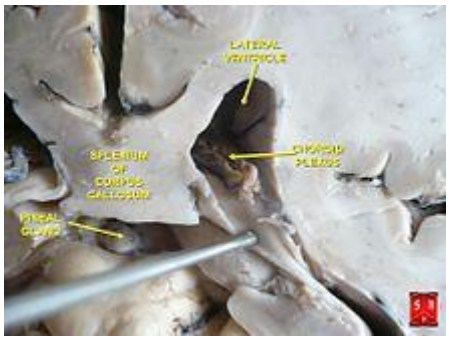


Fig(2-15): **Median sagittal section of brain (person faces to the left). Corpus callosum visible at center, in light gray**

https://en.wikipedia.org/wiki/corpus-collosum#/media /file:Gray720.png

2-2-1 Structure

The posterior (back) portion of the corpus callosum is called the splenium; the anterior (front) is called the genu (or "knee"); between the two is the truncus, or "body", of the corpus callosum. The part between the body and the splenium is often markedly narrowed and thus referred to as the "isthmus". The rostrum is the part of the corpus callosum that projects posteriorly and inferiorly from the anteriormost genu, as can be seen on the sagittal image of the brain displayed on the right. The rostrum is so named for its resemblance to a bird's beak.



Corpus callosum

https://en.wikipedia.org/wiki/corpus-collosum#/media /file:Choroid-plexus.jpg

On either side of the corpus callosum, the fibers radiate in the white matter and pass to the various parts of the cerebral cortex; those curving forward from the genu into the frontal lobe constitute the forceps anterior, and those curving backward into the occipital lobe, the forceps posterior. Between these two parts is the main body of the fibers which constitute the **tapetum** and extend laterally on either side into the temporal lobe, and cover in the central part of the lateral ventricle.

Thinner axons in the genu connect the prefrontal cortex between the two halves of the brain; these fibers arise from a fork-like bundle of fibers from the tapetum, the forceps anterior. Thicker axons in the mid body, or trunk of the corpus callosum, interconnect areas of the motor cortex, with proportionately

more of the corpus callosum dedicated to supplementary motor regions including Broca's area. The posterior body of the corpus, known as the splenium, communicates somatosensory information between the two halves of the parietal lobe and the visual cortex at the occipital lobe, these are the fibers of the forceps posterior.

2-2-2 Variation

Agenesis of the corpus callosum (ACC) is a rare congenital disorder that is one of the most common brain malformations observed in human beings, in which the corpus callosum is partially or completely absent. ACC is usually diagnosed within the first two years of life, and may manifest as a severe syndrome in infancy or childhood, as a milder condition in young adults, or as an asymptomatic incidental finding. Initial symptoms of ACC usually include seizures, which may be followed by feeding problems and delays in holding the head erect, sitting, standing, and walking. Other possible symptoms may include impairments in mental and physical development, hand-eye coordination, and visual and auditory memory. Hydrocephaly may also occur. In mild cases, symptoms such as seizures, repetitive speech, or headaches may not appear for years.

ACC is usually not fatal. Treatment usually involves management of symptoms, such as hydrocephaly and seizures, if they occur. Although many children with the disorder lead normal lives and have average intelligence, careful neuropsychological testing reveals subtle differences in higher cortical function compared to individuals of the same age and education without ACC. Children with ACC accompanied by developmental delay and/or seizure disorders should be screened for metabolic disorders.

In addition to agenesis of the corpus callosum, similar conditions are hypogenesis (partial formation), dysgenesis (malformed), and hypoplasia (underdevelopment, including too thin). Recent studies have also linked

possible correlations between corpus callosum malformation and autism spectrum disorders.

2-2-3 Sexual dimorphism

The corpus callosum and its relation to sex has been a subject of debate in the scientific and lay communities for over a century. Initial research in the early 20th century claimed the corpus to be different in size between men and women. That research was in turn questioned, and ultimately gave way to more advanced imaging techniques that appeared to refute earlier correlations. However, advanced analytical techniques of computational neuroanatomy developed in the 1990s showed that sex differences were clear but confined to certain parts of the corpus callosum, and that they correlated with cognitive performance in certain tests. One recent study using magnetic resonance imaging (MRI) found that the midsagittal corpus callosum cross-sectional area is, on average, proportionately larger in females.

2-2-4 Physiologic imaging

The ability to evaluate the form and function of the human mind has undergone almost exponential growth and a paradigm shift in recent years. Functional magnetic resonance imaging, for example, is now being used to analyze physiology, in addition to the traditional use of MRI for studying anatomy. Using diffusion tensor sequences on MRI machines, the rate at which molecules diffuse in and out of a specific area of tissue, anisotropy (directionality), and rates of metabolism can be measured. These sequences have found consistent sex differences in human corpus callosal morphology and microstructure. Morphometric analysis has also been used to study specific three-dimensional mathematical relationships with MRIs, and have found consistent and statistically significant differences across genders. Specific algorithms have found significant gender differences in over 70% of cases in one review.

2-2-5 Gender identity disorder

Research has been done on the shape of the corpus callosum in those with gender identity disorder. Researchers were able to demonstrate that the shape dimorphism of the corpus callosum at birth in people assigned male at birth who self-identified as female was actually reversed, and that the same held true for people assigned female at birth that self-identified as male, however, the shape of the corpus callosum correlates better with the 'mental sex' of individuals rather than their 'physical sex'. The relationship between the corpus callosum and gender remains an active subject of debate in the scientific community.

The front portion of the corpus callosum has been reported to be significantly larger in musicians than nonmusicians, and to be 0.75 cm^2 or 11% larger in left-handed and ambidextrous people than right-handed people. This difference is evident in the anterior and posterior regions of the corpus callosum, but not in the splenium. Other magnetic resonance morphometric study showed corpus callosum size correlates positively with verbal memory capacity and semantic coding test performance. Children with dyslexia tend to have smaller and less-developed corpus callosum than their nondyslexic counterparts.

Musical training has shown to increase plasticity of the corpus callosum during a sensitive period of time in development. The implications are an increased coordination of hands, differences in white matter structure, and amplification of plasticity in motor and auditory scaffolding which would serve to aid in future musical training. The study found children who had begun musical training before the age of six (minimum 15 months of training) had an increased volume of their corpus callosum and adults who had begun musical training before the age of 11 also had increased bimanual coordination.**(Levitin, Daniel J. 2005)**

Clinical significance: Epilepsy: Electroencephalography is used to find the source of electrical activity causing a seizure as part of the surgical evaluation for a corpus callosotomy. The symptoms of refractory epilepsy can be reduced

by cutting the corpus callosum in an operation known as a corpus callosotomy**.** (James E. 2007)**.**

This is usually reserved for cases in which complex or grand mal seizures are produced by an epileptogenic focus on one side of the brain, causing an interhemispheric electrical storm. The work up for this procedure involves an electroencephalogram, MRI, PET scan, and evaluation by a specialized neurologist, neurosurgeon, psychiatrist, and neuroradiologist before surgery can be considered.(**Web MD. July 18, 2010**)

2-2-6 Other disease: Anterior corpus callosum lesions may result in akinetic mutism or tactile anomia. Posterior corpus callosum (splenium) lesions may result in alexia (inability to read) without agraphia.

The cerebral cortex is divided into two hemispheres, connected by the corpus callosum. A procedure to help patients alleviate the severity of seizures is called split-brain procedure. As a result, a seizure that starts in one hemisphere is isolated in that hemisphere, since a connection to the other side no longer exists. However, this procedure is dangerous and risky.

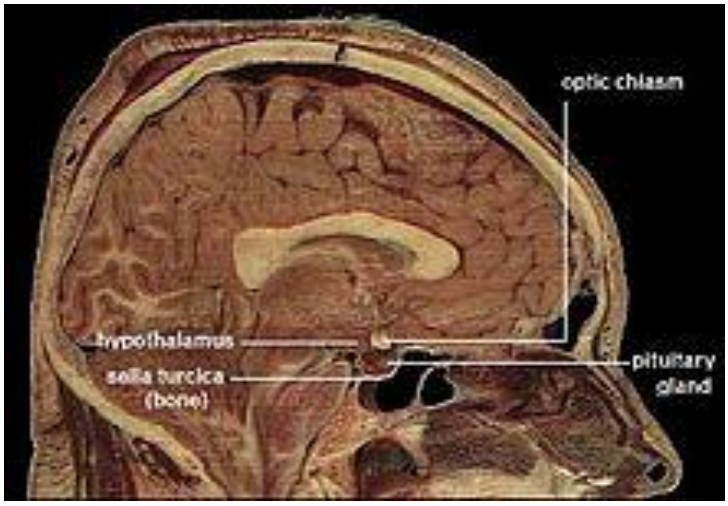
2-2-7 History

The first study of the corpus with relation to gender was by R. B. Bean, a Philadelphia anatomist, who suggested in 1906 that "exceptional size of the corpus callosum may mean exceptional intellectual activity" and that there were measurable differences between men and women. Perhaps reflecting the political climate of the times, he went on to claim differences in the size of the callosum across different races. His research was ultimately refuted by Franklin Mall, the director of his own laboratory.(**Bishop, Katherine M.; Wahlsten, Douglas (1997).** . Of more mainstream impact was a 1982 *Science* article by Holloway and Utamsing that suggested sex difference in human brain morphology, which related to differences in cognitive ability.(**Delacoste-Utamsing, C; Holloway, R. 1982).**

More recent publications in the psychology literature have raised doubt as to whether the anatomic size of the corpus is actually different. A meta-analysis of 49 studies since 1980 found that, contrary to de Lacoste-Utamsing and Holloway, no sex difference could be found in the size of the corpus callosum, whether or not account was taken of larger male brain size.[23] A study in 2006 using thin slice MRI showed no difference in thickness of the corpus when accounting for the size of the subject. (**Luders, Eileen; Narr, Katherine L.; Zaidel, Eran; Thompson, Paul M.; Toga, Arthur W., 2006)**

2-2-8 Animals other than man:

The corpus callosum is found only in placental mammals (the eutherians), while it is absent in monotremes and marsupials, as well as other vertebrates such as birds, reptiles, amphibians and fish. (Other groups do have other brain structures that allow for communication between the two hemispheres, such as the anterior commissure, which serves as the primary mode of interhemispheric communication in marsupials, and which carries all the commissural fibers arising from the neocortex (also known as the neopallium), whereas in placental mammals, the anterior commissure carries only some of these fibers. In primates, the speed of nerve transmission depends on its degree of myelination, or lipid coating. This is reflected by the diameter of the nerve axon. In most primates, axonal diameter increases in proportion to brain size to compensate for the increased distance to travel for neural impulse transmission. This allows the brain to coordinate sensory and motor impulses. However, the scaling of overall brain size and increased myelination have not occurred between chimpanzees and humans. This has resulted in the human corpus callosum's requiring double the time for interhemispheric communication as a macaque's. *(Gupta, 2008)*



Fig(2-16): ***Sagittal post mortem section through the midline brain. The corpus callosum is the curved band of lighter tissue at the center of the brain above the hypothalamus. Its lighter texture is due to higher myelin content, resulting in faster neuronal impulse transmission.***

www.eucalyptusike.com/sitebuilder/images/corpus-col.jpg

The fibrous bundle as which the corpus callosum appears, can and does increase to such an extent in humans that it encroaches upon and wedges apart the hippocampal structures.(Kosar Ml, 2012)

Corpus callosum

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A

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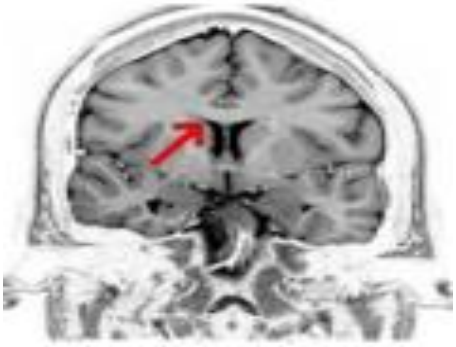

B

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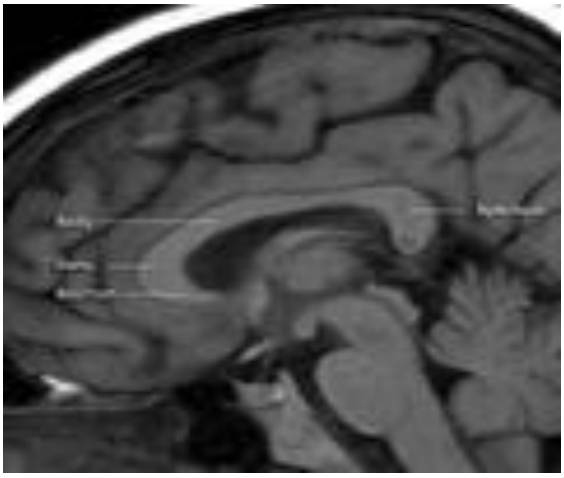

C

Corpus callosum parts on MRI

Fig(2-17): Coronal T2 (grey scale inverted) MRI of the brain at the level of the caudate nuclei emphasizing corpus callosum

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Fig(2-18) Ventricles of brain and basal ganglia. Superior view. Horizontal section. Deep dissection

http://upload.wikipedia.org/wikipedia/commons/8/81/slide2GRe.jpg

Fig(2-19) : Ventricles of brain and basal ganglia. Superior view. Horizontal section. Deep dissection

http://upload.wikipedia.org/wikipedia/commons/8/82/slide3GRe.jpg

2-3 physiology

2-3-1 Physiology of the Forebrain (Proencephalon)

2-3-1-1 Introduction

The forebrain (Proencephalon) is the largest part of the brain, most of which is cerebrum. Other important structures found in the forebrain include the thalamus, the hypothalamus and the limbic system. The cerebrum is divided into two cerebral hemispheres connected by a mass of white matter known as the corpus callosum. Each hemisphere is split into four lobes; the frontal, parietal, occipital and temporal lobes. The surface of each hemisphere is made up of grey matter known as the cerebral cortex and is folded to increase the surface area available within the skull. The cortex has roles within perception, memory and all higher thought processes. Inside the cortex is the white matter, within which are a number of nuclei (grey matter), known as the basal nuclei. The basal nuclei receive information from the cortex to regulate skeletal movement and other higher motor functions. The thalamus functions to relay sensory information to the cerebral cortex and the hypothalamus, regulating visceral functions including temperature, reproductive functions, eating, sleeping and the display of emotion. The limbic system describes a collection of structures within the forebrain, including the amygdala and hippocampus, also known as the 'emotional brain'. It is important in the formation of memories and in making decisions and learning.

Table (2-2) Forebrain Structure and Function

Brain Region	Structure	Function
Diencephalon	Thalamus	Organising sensory information
Diencephalon	Hypothalamus	Endocrine System, Thermoregulation
Diencephalon	Pituitary	Endocrine System
Telencephalon	Cerebral Cortex	Conciousness, language etc
Telencephalon	Limbic System	Memory, motivation, emotion
Telencephalon	Olfactory Bulb	Smell

2-3-1-3 Thalamus

The thalamus has many functions including processing and relaying sensory information selectively to various parts of the cerebral cortex, translating signals to the cerebral cortex from lower centres including auditory, somatic, visceral, gustatory and visual systems and also regulating states of sleep and wakefulness. The thalamus plays a major role in regulating arousal, levels of consciousness and levels of activity.

2-3-1-4 Hypothalamus

The function of the hypothalamus is mainly related to the overall regulation of the Endocrine System. The hypothalamus is closely related to the pituitary gland, controlling a large proportion of the activity going to it. For a more detailed analysis of the function of this part of the brain, please use the link: Hypothalamus Anatomy and Physiology.

2-3-1-5 Pituitary

The function of the pituitary is mainly related to the production of hormones as part of the Endocrine System. For further information on the pituitary gland please use this link: Pituitary Gland Anatomy and Physiology.

2-3-1-6 Cerebral Cortex

The cerebral cortex is essential for memory, attention, awareness, thought, language and consciousness. The outer layers of the cerebrum are made up of grey matter. Grey matter is formed by neurons and their unmyelinated fibres. The white matter below the grey matter of the cortex is formed predominantly by myelinated axons (myelin is white in appearance). The surface of the cerebral cortex is folded in mammals; more than two thirds of the surface is within the grooves or "sulci". The cerebral cortex is connected to structures such as the thalamus and the basal ganglia, sending information to them along efferent connections and receiving information from them via afferent connections. Most sensory information is routed to the cerebral cortex via the

thalamus. The cortex is commonly described as comprising three parts; sensory, motor and association areas.

2-3-1-7 Sensory Areas

The sensory areas are the areas that receive and process information from the senses. Inputs from the thalamus are called primary sensory areas. Vision, hearing, and touch are processed by the primary visual cortex, primary auditory cortex and primary somatosensory cortex. The two hemispheres of the cerebral cortex receive information from the opposite (contralateral) side of the body. Areas with lots of sensory innervation, such as the fingertips and the lips, require more cortical area to process finer sensation. The association areas of the brain function to produce a perception of the world enabling an animal to interact with their environment effectively. There are a number of anatomical areas of the brain responsible for organising this sensory information. The parietal lobe is located within the dorsocaudal aspect of the cortex. The temporal lobes are located laterally and the occipital lobes are located in the caudal most aspect of the cortex. The frontal lobe or prefrontal association complex is involved in planning actions and movement.

2-3-1-8 Motor Cortex

The motor cortex areas of the brain are located in both hemispheres of the cortex and are shaped like a pair of headphones stretching from ear to ear. The motor areas are related to controlling voluntary movements, especially fine movements. There are two main types of connection between the motor cortex and motor neurones found in the ventral horn of the spinal cord; the Pyramidal tracts and the Extrapyramidal tracts.

Pyramidal tract connections are direct with no synapses in the brain stem. Axons pass through the ventral aspect of the medulla oblongata. The **extrapyramidal tracts** pass through the medulla oblongata outside the ventral pyramidal tracts and have synapses within the brain stem nuclei. These synapses

make it possible for signals travelling down the extrapyramidal horns to be influenced by other areas of the brain including the cerebrum.

The pyramidal tracts are responsible for aspects of fine motor skills that require a degree of conscious thought and concentration. The extrapyramidal tracts are generally responsible for activation of larger muscle groups and often work in a coordinated manner to achieve smooth synchronous movements.

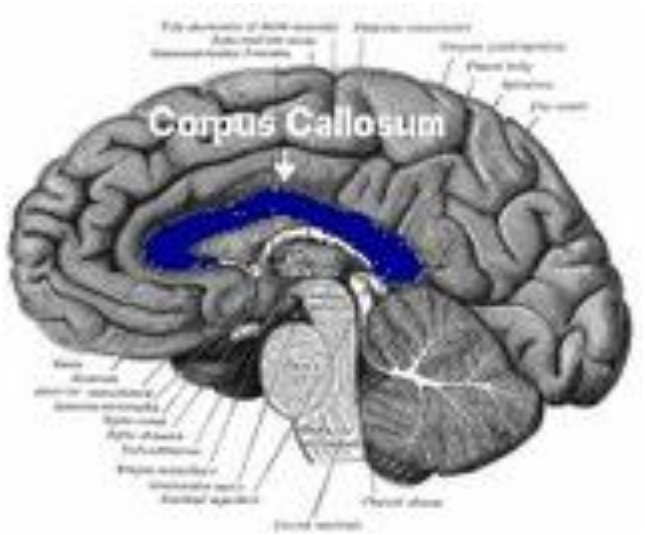
2-3-1-9 Limbic System

The Limbic system is made up of parts of the brain bordering the corpus collosum. The Limbic system contains areas of cerebral cortex, the cingulate gyrus (dorsally), the parahippocampus gyrus (ventrally), the amygdala, parts of the hypothalamus (mamillary body) and the hippocampus. The Limbic system is principally responsible for emotions and the various types of emotion can affect the activity of the Autonomic Nervous System, facilitated by the hypothalamus. For example, anger can lead to increased heart rate and blood pressure.

2-3-1-10 Olfactory Bulb

The olfactory bulb is responsible for olfaction and the bulb itself is located within the rostral forebrain area, supported by the cribiform plate and the ethmoid bone. The olfactory nerves are connected directly to the limbic system which is unique among mammalian sensory organs. As a result, olfaction plays a central role and is particularly important in regulating/stimulating sexual behavior in many species. *Ventral Brain with Olfactory bulbs rostral* (Human),(Grays Anatomy, 1918)

2-3-2 Physiology of the corpus callosum



Fig(2-20) : **Physiology of the corpus callosum**

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The **corpus callosum (CC)** links the cerebral cortex of the left and right cerebral hemispheres and is the largest fibre pathway in the brain.

Gross anatomy

The corpus callosum is **~10cm** in length and is C-shaped, like most of the supratentorial structures, in a gentle upwardly convex arch.

It is divided into four parts (anterior to posterior):

- rostrum (continuous with the lamina terminalis)
- genu
- trunk/body
- splenium

Relations

Immediately above the body of the CC, lies the interhemispheric fissure in which runs the falx cerebri, the anterior cerebral vessels. The superior surface of

the CC is covered by a thick layer of grey matter known as the indusium griseum. On either side, the body is separated from cingulate gyrus by the callosal sulcus. Attached to the concave undersurface of the CC is the septum pellucidum anteriorly, and the fornix and its commissure posteriorly.

Although the CC can be seen as a single large fibre bundle connecting the two hemispheres, a number of individual fibre tracts can be identified. These include:

Genu: forceps minor : connect medial and lateral surfaces of the frontal lobes. **Rostrum**: connecting the orbital surfaces of the frontal lobes **Trunk** (body): pass through the corona radiata to the surfaces of the hemispheres. Trunk and splenium: **tapetum;** extends along the lateral surface of the occipital and temporal horns of the lateral ventricle. **Splenium**: forceps major; connect the occipital lobes.

These connections can also be divided into: Homotopic connections those that link similar regions on each side e.g. visual fields of motor/sensory areas of the trunk. Heterotopic connections: those that link dysimilar areas

Blood supply

The corpus callosum (CC) has a rich blood supply, relatively constant and is uncommonly involved by infarcts. The majority of the CC is supplied by the pericallosal arteries (the small branches and accompanying veins forming the pericallosal moustache) and the posterior pericallosal arteries, branches from the anterior and posterior cerebral respectively. In 80% of patients additional supply comes from the anterior communicating artery, via either subcallosal artery or median callosal artery. (Henry Gray, et al , 1995)

- subcallosal artery (50% of patients) is essentially a large version of a hypothalmic branch, which in addition to supplying part of the hypothalamus also supplies the medial portions of the rostrum and genu
- median callosal artery (30% of patients) can be thought of as a more extended version of the subcallosal artery, in that it travels along the same

course, supplies the same structures but additionally reaches the body of the corpus callosum

- posterior pericallosal artery (also known as splenial artery) supplies a variable portion of the splenium. Its origin is inconstant, arising from P3 or branches thereof.

After periods of disinterest, neurosurgeons' attention to the corpus callosum has been reawakened for a variety of reasons. For centuries, the large size, central location, and widespread connections of the corpus callosum stimulated investigations, which were motivated as much by scientific curiosity as by therapeutic considerations. Callosal physiology has more recently been important to surgeons concerned primarily with other structures, including those neighboring the third ventricle, which can be approached through the corpus callosum. But the principal motivation has been the role of the corpus callosum in the generation of seizures. At the end of the 19th century and on two other separate occasions in the 20th century, callosotomy was considered as a treatment for seizure disorders. Before 1900, less obviously around 1940, and most clearly in the 1960s, these therapeutic considerations were stimulated by animal experimentation. One theme of this chapter is the reciprocal interaction of surgical therapy and laboratory experimentation: in particular, the most recent therapeutic use of callosotomy has been accompanied by widespread physiological and psychological interest in this conspicuous brain structure. In this chapter we consider first a brief history of studies of the corpus callosum. Then follows a chronological account of interest in callosotomy as a treatment for epilepsy. (Henry Gray, et al , 1995)

2-3-3 Studies of Callosal Function

Studies of the corpus callosum were first undertaken by the Humoral Anatomists. These were the writers of antiquity whose concepts of brain function emphasized the contents of the brain cavities and the flow of various fluids such as air, phlegm, cerebrospinal fluid, and blood. For them, the corpus

callosum seemed largely a supporting structure. This view persisted for a millennium. Even that originally (**Renaissance genius, Andreas Vesalius,** 1514-1564), believed that the corpus callosum served mainly as **a mechanical support**, maintaining the integrity of the various cavities. In 1543, he wrote: There is a part [whose] external surface is gleaming white and harder than the substance on the remaining surface of the brain. It was for this reason that the ancient Greeks called this part "tyloeides" ["callosus" in Latin] and, following their example, in my discourse I have always referred to this part as the corpus callosum. If you look at the right and left of the brain, and also if you compare the front and rear, the corpus callosum is observed to be in the middle of the brain; Indeed, it relates to the right side of the cerebrum more than to the left; then it produces and supports the septum of the right and left ventricles; finally, through that septum it supports and props the [fornix] so that it support it, so as to not collapse and, to the great detriment (observe and control as well as integrate with the other side) of all the functions of the cerebrum, crush the cavity common to the two [lateral] ventricles of the cerebrum.(D.W.Roberts , et al , 1995).

In the 17th century, the "traffic anatomists" took a major step forward. It was at about the time of (**Thomas Willis ,1621-1675)** that anatomists began thinking more in terms of a traffic or communication between the more solid parts of the brain. This view became quite explicit in the statement of **(Felix ,1748-1794)** who wrote in 1784: "It seems to me that the commissures are intended to establish sympathetic communications between different parts of the brain, just as the nerves do between different organs and the brain itself.

For over two centuries, beliefs about callosal function consisted almost solely of inferences from its central location, widespread connections, and large size (larger than all of those descending and ascending tracts, taken together, that connect the cerebrum with the outside world). Among others, **(Willis, François de la Peyronie ,1678-1747),** and (**Giovanni Lancisi ,1654-1720)** thought the

corpus callosum a likely candidate for "the seat of the soul," or they used some other expression intended to cover that highest or ultimate liaison (communication) which brings coherent, vital unity to a complex assemblage.

The observations of the early anatomists have often been supported by subsequent anatomical observations, including the large number of callosal fibers (at least 200 million of them). Because the callosal fibers interconnect so much of the cerebral cortex, especially that cortex considered associative, it has often been suggested that they serve some of the "highest," most educable, and characteristically human functions of the cerebrum.

Inference of function from observable structure is time-honored and productive; however, such inference has its limitations. The physiological evidence has only partially sustained anatomical inference. We now know from various observations (notably the split brain) that the corpus callosum is indeed an important integrative structure; we also know that it is neither sufficient nor indispensable, providing only one of a number of integrative mechanisms. (D.W.Roberts , et al , 1995).

That the corpus callosum is not the exclusive "seat of the soul" is evident from the apparent normality in social situations of patients who have had complete callosotomies.That it is an important integrating mechanism is clear from the peculiarities of such patients. These include, among other things, a unilateral tactile anomia, a left hemialexia. And a unilateral apraxzia. That is, for the right-hander with complete callosotomy, there is an inability to name aloud objects felt with the left hand, an inability to read aloud written material presented solely to the left half-field of vision, and an inability to execute with the left hand actions verbalIy named or described by the examiner. The apraxia usually recedes in a few months, whereas the hemialexia and unilateral anomia persist for years. Such deficits are now readily demonstrable in individuals who have had surgical section of the corpus callosum. But these deficits were first

recognized in patients with vascular disease that caused very complex and evolving syndromes. (D.W.Roberts , et al , 1995).

In the closing decades of the 19th century ,there emerged a group of neurologists whose discoveries and formulations are still at the core of current clinical knowledge. Among them were Carl (Wernicke,1848-1905), (Hugo Liepmann,1863-1925), (J. Jules Dejerine,1849-1917), and (Kurt Goldstein ,1878-1965), who interpreted various neurological symptoms as resulting from disconnection, including interruption of information flow through the corpus callosum.

The concept of apraxia was developed by Liepmann expressly to describe a patient who could carry out commands with one of his hands but not with the other. In 1908, Liepmannand Maas *26* described a right-handed patient whose callosal lesion caused a left apraxia as well as a left-handed agraphia (an inability to write) in the absence of aphasia. These disabilities have subsequently been observed many times. Unilateral apraxia and unilateral agraphia are not always present, and they may subside when a stroke victim progressively recovers, but they remain among the cardinal signs of callosal interruption.

Liepmann considered the corpus callosum instrumental in most left-hand responses to verbal command: the verbal instruction was comprehended only by the left hemisphere, and the left hand followed instructions delivered not by a directly descending pathway (which we now call "ipsilateral control") but by a route involving callosal interhemispheric transfer from left to right and then by right hemisphere control of the left hand (what we now call "contralateral control"). (D.W.Roberts , et al , 1995).

Necessarily then, callosal interruption would result in an inability to follow verbal commands with the left hand, although there would be no loss of comprehension (as expected from a left hemisphere lesion) and no weakness or incoordination of the left hand (as could result from a right hemisphere lesion).

This view was largely ignored or rejected (particularly in the English-speaking countries) for nearly half a century.

(Norman Geschwind ,1926-1984) suggested that there was a widespread revulsion against attempts to link brain to behavior, associated with the rise of psychoanalysis (personal communication). He had another sociological explanation:

Henry Head had been shrewd enough to point out that much of the great German growth of neurology had been related to their victory in the Franco-Prussian war. He was not shrewd enough to apply this valuable historical lesson to his own time and to realize that perhaps the decline of the vigor and influence of German neurology was strongly related to the defeat of Germany in World War I and the shift of the center of gravity of intellectual life to the English-speaking world, rather than necessarily to any defects in the ideas of German scholars. *19* As Harrington put it, *2l* ways of thinking about the brain (i.e., laterality and duality) which seem natural enough now had "vanished from the working world view" for nearly 50 years. She has made available in scholarly detail the popularity of these ideas (laterality and duality) in the 19th century, and their eventual re-emergence in the 1960s. Chapter 9 of Harrington's book*2l* is devoted to the causes of this long eclipse. She was particularly critical of (Henry Head ,1861-1940), whose highly selective reference to John Hughlings Jackson, she wrote, "borders on intellectual dishonesty."

Besides the sociological aspects, other factors were involved. There was widespread reluctance to consider callosal disconnection as the efficient cause of deficits such as unilateral apraxia or hemialexia occurring in patients with lesions (e.g., tumors or infarctions) involving the corpus callosum. This reluctance developed in large part because surgical interruption of the corpus callosum had not been found to cause the same deficits. Walter (Dandy ,1886-1946) went so far as to say in 1936: "The corpus callosum is sectioned longitudinally; no symptoms follow its division. This simple experiment puts an

end to all of the extravagant hypotheses on the functions of the corpus callosum. Even more persuasive were the negative tests performed by (Andrew J. Akelaitis ,1904-1955)1 on patients who had callosal section. By the end of the 1950s, Fessard summarized the view that was then generally accepted: "There is a great deal of data showing [that] section of important associative white tracts such as the corpus callosum does not seem to affect mental performances. Other similar observations in man or animals are now accumulated in great number and variety. (D.W.Roberts , et al , 1995).

We now realize that most of the negative findings resulted from two sources:

1. When surgical section of the commissures is incomplete, a remarkable capacity for maintaining cross-communication between the hemispheres may be retained with quite small commissural remnants, particularly when the part remaining is at the posterior end of the corpus callosum (in other words, the splenium). (D.W.Roberts , et al , 1995).

2. Negative findings often result from the use of inappropriate or insensitive testing techniques. What one finds depends on what one looks for; although Dandy" said that callosal section produces no observable deficits, among his own patients was one reported by Trescher and Ford to have hemialexia.

Essential to the resurrection of the callosal disconnection view was the ability to observe repeatedly and appropriately under controlled, prospective circumstances the results of callosotomy in humans. This was facilitated by the use of complete callosotomy as a treatment for epilepsy, which, in turn, had been made possible by cat and monkey experiments beginning in the 1950s. Forty years of experimentation with laboratory animals and 30 years of experience with callosotomized humans have by now firmly established the principal features of callosal section and facilitated the more precise interpretation of deficits following naturally occurring lesions. (D.W.Roberts , et al , 1995).

The impression is gained from this small number of observations that the type of case in which section of commissural fibers in the corpus callosum is most favorable is the one in which a large cortical or subcortical scar exists.

2-3-4 The Corpus Callosum and Epilepsy

The famous experiments of Gustav Fritsch (1838-1891) and Eduard Hitzig (1838-1907) in 1870 showed that there was a limited region of the cerebral cortex (the "motor cortex"), electrical stimulation of which resulted in movements of the contralateral limbs."," In two of their dogs, removal of the electrically excitable cortex resulted in subsequent incoordination of the contralateral limbs. In another two dogs, tetanization caused "epileptic attacks" beginning first in the contralateral limbs and then becoming generalized. The generalization of the "epileptic attacks" could be interpreted, in retrospect, as due to transmission across the corpus callosum. (Alexander G. et al 2013)

A next step was taken by Bubnoff and Heidenhain in 1881. They stimulated the white matter exposed by ablation of the motor cortex. This stimulation could produce convulsive movements in the unparalyzed ipsilateral limbs. They concluded that excitation had spread across the corpus callosum to involve the motor cortex of the opposite hemisphere. A few years later, in 1886, (Sir Victor Horsley,1857-1916) lectured on the effectiveness of cutting the corpus callosum to prevent the spread of seizures. He recognized (as had Bubnoff and Heidenhain) that subcortical circuits could maintain convulsive activity once it began, but emphasized the role of cerebral cortex in the initiation of convulsions. (Alexander G. et al 2013)

In succeeding decades, the possible role of the corpus callosum in seizure spread was studied in experimental animals by many other investigators. When Spiegel" reviewed the physiology of epilepsy in 1931, he emphasized the common finding that generalized convulsions could occur after the corpus callosum connections had been severed. His own experiments included section of all crossing fibers down to the rhombencephalon and he stated that "even

after this operation, we could observe that general clonic convulsions developed following one-sided cortical stimulation." He also described experiments with a sagittal section of the rhombencephalon in the midline, again with generalized convulsions being possible from stimulation of one hemisphere. Evidently, generalization can occur through fibers that cross the midline at several levels. Many years before, (John Hughlings Jackson ,1835-1911) had asserted that whatever its behavioral manifestations, seizure activity was characterized by an excessive discharge (we now call it "hypersynchronous and self-maintaining") of nerve cells. In 1878, he wrote: "A convulsion is but a symptom, and implies only that there is an occasional, an excessive, and a disorderly discharge of nerve tissue on muscles. Elsewhere he wrote: Scientifically, I should consider epilepsies on the hypothesis that the paroxysm of each is dependent on a sudden temporary excessive discharge of some highly unstable region of the cerebral cortex. There is, in other words, in each epilepsy a "discharging lesion" [which] leads to secondary discharge of healthy cells in other centers. This assertion met with considerable resistance at the time but was ultimately confirmed by electroencephalographic (EEG) studies. These included animal experiments by Moruzzi, 28 among others. Moruzzi observed that epileptiform EEG activity induced by electrical stimulation in one hemisphere promptly appeared in the other with a latency consistent with the conduction speed of callosal fibers, and this spread could be prevented by callosotomy. However, this finding did not negate the possibility of spread via other routes.

The multiplicity of routes for seizure spread rendered unattractive the idea of cutting the corpus callosum for treatment of epilepsy, particularly in view of the technical difficulties which this would involve. The feasibility of cutting the corpus callosum was subsequently emphasized in 1936 by Dandy, who used this approach to reach midline tumors. But neither he nor others of the time recommended callosotomy for epilepsy. (Alexander G. et al 2013)

The first callosotomies for epilepsy were reported in 1940 by Van Wagenen and Herren; they operated on their first case on February 6, 1939. (William P. Van Wagenen ,1897-1961) was at that time Chief of Neurosurgery at the University of Rochester, Strong Memorial Hospital. The rationale given for this procedure was their observation of two cases in which a callosal tumor had lessened seizure frequency and two cases of vascular insult that stopped the seizures altogether. Their paper contained no references; hence it is not clear if the authors knew of Spiegel's 1931 report 39 or the material that he summarized. It seems less likely that they were aware of Mortuzzi's investigations in the mid-1930s. Nor is it clear if they were aware of the work of Erickson. In 1940, (Theodore Erickson ,1906-1986)16 had performed experiments on monkeys showing a role of the corpus callosum in seizure spread, and his report was published in the preceding volume of the same journal. One might assume that Erickson's animal experiments at the Montreal Neurological Institute were known to Van Wagenen, since the neuroscience community was quite small in those days. Moreover, both attended meetings of the American Neurologic Association. Robert Joynt,*25* who arrived at the University of Rochester as Chairman of Neurology in 1966, hasemphasized that the Van Wagenen series was undertaken "solely on clinical observations [which were personally made] by the two authors." Joynt focused special attention on the summary of the Van Wagenen-Herren paper. Parts of the summary are worth repeating here because their conclusions have remained largely correct after more than 50 years. (Alexander G. et al 2013)

Van Wagenen and Herren summarized their first 10 experiences with callosotomy as follows:

The impression is gained from this small number of observations that the type of case in which section of commissural fibers in the corpus callosum is most favorable is the one in which a large cortical or subcortical scar exists . (Alexander G. et al 2013)

Whether section of various commissural pathways to prevent the spread of an epileptic wave is indicated for patients having multiple irritable fociis a matter for future study ... the observation on patients having jacksonian seizures on the right side after section of the corpus callosum on one occasion and on the left side on another suggests that there are at least bilateral foci from which seizures may originate. (Alexander G. et al 2013)

The inhibitory effect of the cortex of one hemisphere on the activity of the other must also be considered seriously ... it may be that in certain instances the cortex of one hemisphere may inhibit abnormal activity of an abnormal zone and that section of commissural pathways is contraindicated. (Alexander G. et al 2013)

Section of the commissural pathways contained in the corpus callosum may be carried out without any untoward effect on the patient. Such a section may serve to limit the spread of an epileptic wave to the opposite hemisphere. When such limitation occurs, the patients do not seem to lose consciousness or have generalized convulsions.

Although Van Wagenen and Herren seemed pleased with their results, no one else took up the operation. This may have been in part because of the onset and continuation for 5 years of World War 11, or longer term outcomes may have been unfavorable and generally known although unpublished (see the section on personal recollections). An important factor was the growing conviction, reaching a peak in the 1950s that the reticular formation and its rostral targets in the thalami are of particular importance for seizure spread. As Penfield and jasper stated in one of the great classics of epileptology: It seems reasonable to assume, therefore, that generalization of the motor seizure does not take place by spread of excitation through cortical circuits. It must spread through the more closely interrelated neuronal network of the higher brain stem, in a centrencephalic system with symmetrical functional relationships to both sides of the body."'

The irrelevance of callosal transmission for generalization of unilateral seizures was also suggested by the occasional recurrence of generalized convulsions in humans with hemispherectomy.Indeed, in a few experiments generalized convulsions could be produced by Van Harreveld in dogs subsequent to bilateral decortication .

In spite of the foregoing, a number of other considerations discussed below suggested the possibility of improvement of otherwise untreatable seizure disorders in carefully chosen cases. Briefly, the reintroduction in 1962 of callosotomy together with anterior and hippocampal commissurotomy as a treatment for medically intractable epilepsy was stimulated and indeed made possible by animal experimentation involving similar procedures in cats and monkeys (e.g., Sperry and Myers) . Because of the remarkable improvement of two patients treated by Bogen et al, we continued to offer the operation. A few years later we briefly reported our rewarding results in nine of 10 cases, each having at least 2 years follow up, concluding: "It thus appears that the combination of cerebral commissurotomy plus postoperative medication has limited propagation of seizure activity from a cortical focus. The improved status of these patients made possible their participation in a long and still continuing series of neuropsychological investigations. These investigations, which contributed to Roger Sperry's Nobel Prize in 1981, supported two generalizations: that there was incomplete but substantial hemispheric independence, and complementary hemispheric specialization. In a classic paper, Sperry wrote: Although some authorities have been reluctant to credit the disconnected minor hemisphere even with being conscious, it is our own interpretation based on a large number and variety of nonverbal tests, that the minor hemisphere is indeed a conscious system in its own right, perceiving, thinking, remembering, reasoning, willing, and emoting, all at a characteristically human level, and that both the left and the right hemisphere

may be conscious simultaneously in different, even in mutually conflicting, mental experiences that run along in parallel. (Alexander G. et al 2013)

Though predominantly mute and generally, inferior in all performances involving language or linguistic or mathematical reasoning, the minor hemisphere is nevertheless clearly the superior cerebral member for certain types of tasks. Largely they involve the apprehension and processing of spatial patterns, relations, and transformations. They seem to be holistic and unitary rather than analytic and fragmentary, and orientational more than focal, and to involve concrete perceptual insight rather than abstract, symbolic, sequential reasoning. However, it yet remains for someone to translate in a meaningful [i.e., physiological] way the essential right-left characteristics. (Alexander G. et al 2013)

1) The data, as well as what they implied, were sufficiently dramatic to attract increasing media attention. Much of this was hastily written and often sensationalized. According to the New Yorker magazine of November 8, 1976 (p 36), "The corpus callosum is an inch long An article in the New York Times Magazine on September 9, 1973, included an artist's drawing of a split-brain patient wielding a hatchet in the left hand which was being restrained by the right hand. Less esteemed media outlets were worse, and there were innumerable cartoons. The media pushed the popularity of the "right brain/left brain" story to fad proportions, reaching an almost frenzied peak by 1980. This led not only to simplistic degradation, probably inevitable with popularization, but also to exploitation. Commercially motivated entrepreneurs promised to educate people's right hemispheres in short order, sometimes even overnight, ignoring the lengthy, arduous training necessary for mature competence.

This was followed by a reaction or backlash, much of which involved the debunking of extravagant claims." Some of it, however, was more revisionist; that is, some writers challenged the basic observations. A notable example is the recent explicit rejection of hemispheric specialization by Efron "I have offered

elsewhere 5 some tentative evaluations of these events, which provide an example of how 20th century neurosurgery has influenced both academic and popular psychology".

Our reports of therapeutic success with callosotomy were followed by a few others (Luessenhop et al). However, wider acceptance of this procedure was made possible only by the sustained effort during the decade of the 1970s of Donald H. Wilson, and coworkers, particularly Alexander Reeves, at Dartmouth Medical 17School. By 1982, at the Dartmouth conference organized by Wilson and Reeves, the use of callosotomy for epilepsy was reported from six more clinical centers. There had also been a burgeoning of experimental studies, many of them presented at that conference. Both the clinical and experimental contributions were subsequently included in a book edited by Reeves. During the 1980s, callosotomy (either complete or more often partial) became an established procedure. In the words of Spencer et al:

Over the past decade, corpus callosum section has become a widely accepted, relatively safe, clearly needed, broadly practiced, and continually evolving addition to the medical treatment of certain types of severe and uncontrolled seizures in certain types of patients who are not candidates for respective procedures. Over a span of about 30 years, during which callosotomy came to be more favorably viewed as a treatment for epilepsy, increased familiarity with both the anatomy and the physiology of the corpus callosum has encouraged the use of partial callosotomy as an approach to the third ventricle and other midline structures.

Concluding Remarks about physiology

The multifactorial causation of postcallosotomy mutism affords a measure of our ignorance, representing as it does the difficulties in predicting the likelihood of this usually transient but nonetheless distressing malfunction. On the other hand, the very existence of this riddle affords an opportunity for someone to unravel it. Likewise, the lack of replicate signs or symptoms from section of the

anterior two thirds of the corpus callosum represents a territory still unknown and awaiting exploration.

That the transcallosal approach to the third ventricle is largely without obligatory physiological cost is both a boon to the operator and a challenge to the scientist. Neurosurgeons have historically been both therapeutic and investigative, and we can expect that continued exploitation of the transcallosal approach will benefit our patients both at the time of treatment and by augmenting our understanding of what Bremer once called, "the highest and most elaborate activities of the brain."

Summary of Corpus Callosum physiology:

The corpus callosum is a thick band of nerve fibers that divides the cerebrum into left and right hemispheres. It connects the left and right sides of the brain allowing for communication between both hemispheres. The corpus callosum transfers motor, sensory, and cognitive information between the brain hemispheres.

Function:

The corpus callosum is involved in several functions of the body including:

- Communication Between Brain Hemispheres
- Eye Movement
- Maintaining the Balance of Arousal and Attention
- Tactile Localization

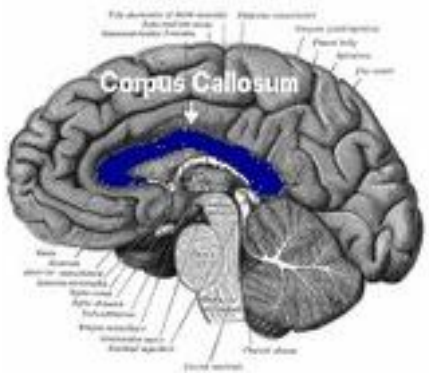

Fig (2-21) :Corpus Callosum. Credit: Gray's Anatomy
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2-4 pathology

2-4-1 Disorders of corpus callosum

2-4-2 Outline:

Disorders of corpus callosum include Agenesis of corpus callosum , Tumors , Lipoma, Glioblastoma multiforme, Lymphoma, Juvenile pilocytic astrocytoma , Demyelinating diseases, Multiple sclerosis Progressive multifocal leukoencephalopathy, Marchiafava-bignami disease, Vascular which include Infarction and Arteriovenous malformations , Trauma , Miscellaneous lesions , Lesions of corpus callosum in psychiatric diseases .

2-4-3AGENESIS OF CORPUS CALLOSUM

Agenesis of the corpus callosum (ACC) is a rare birth defect (congenital disorder) in which there is a complete or partial absence of the corpus callosum. The development of the fibers that would otherwise form the corpus callosum become longitudinally oriented within each hemisphere and form structures called Probst bundles. In addition to agenesis of the corpus callosum, other congenital callosal disorders include :

1. Hypogenesis (partial formation), 2. Dysgenesis (malformation) of the corpus callosum, 3. Hypoplasia (underdevelopment) of the corpus callosum. Diagnosis of callosal disorders can be diagnosed only through a brain scan; they may be diagnosed through an MRI, CT scan, prenatal ultrasound, or prenatal MRI.

Cause of agenesis of the corpus callosum: is caused by disruption to development of the fetal brain between the 3rd and 12th weeks of pregnancy. In most cases, it is not possible to know what caused an individual to have ACC or another callosal disorder. However, research suggests that some possible causes may include chromosome errors, inherited genetic factors, prenatal infections or injuries, prenatal toxic exposures, structural blockage by cysts or other brain abnormalities, and metabolic disorders. Signs and symptoms vary greatly among individuals some characteristics common in individuals with callosal disorders include 1. Poor motor coordination, 2. Delays in motor milestones

such as sitting and walking, 3. Delayed toilet training, 4. Chewing and swallowing difficulties 5. Vision impairments, 6. Hypotonia 7. Low perception of pain. Researches: shown to have some cognitive disabilities (difficulty in complex problem solving) and social difficulties (missing subtle social cues), even when their intelligence quotient is normal. Other characteristics sometimes associated with callosal disorders include seizures, spasticity, early feeding difficulties and/or gastric reflux, hearing impairments, abnormal head and facial features, and mental retardation. Associated syndromes like ACC can occur as an isolated condition or in combination with other cerebral abnormalities, including Arnold-chiari malformation, Dandy-walker syndrome, Andermann syndrome (motor and sensory neuropathy), Schizencephaly (clefts or deep divisions in brain tissue), Holoprosencephaly (failure of the forebrain to divide into lobes.). Girls may have a gender-specific condition called Aicardis syndrome, which causes severe mental retardation, seizures (infantile spasms), abnormalities in the vertebra of the spine, and lesions (lacunae) on the retina of the eye. ACC can also be associated with malformations in other parts of the body, such as midline facial defects.The effects of the disorder range from subtle or mild to severe, depending on associated brain abnormalities.

Treatment: There are currently no specific medical treatments for callosal disorders; it usually involves management of symptoms and seizures if they occur. Patients may benefit from a range of developmental therapies, educational support, and services. Prognosis varies depending on the type of callosal abnormality and associated conditions or syndromes.ACC does not cause death in the majority of children. Mental retardation does not worsen. Although many children with the disorder have average intelligence and lead normal lives, neuropsychological testing reveals subtle differences in higher cortical function compared to individuals of the same age and education without ACC.

Tumors of the corpus callosum, especially those involving the anterior portion, frequently cause psychiatric and behavioral symptoms. These include Catatonia, Depression, Psychotic symptoms, and Personality changes. Definitive brain imaging studies are indicated in psychiatric patients with new or pre-existing psychiatric and behavioral symptoms accompanied by focal neurological findings atypical presentation.

Lipoma: Intracranial lipomas are rare developmental lesions of the central nervous system, which are usually asymptomatic and discovered incidentally. They mainly occur in the region of the corpus callosum and the pericallosal cistern, accounting for up to 65% of all intracranial lipomas and frequently associated with callosal dysgenesis 2-year-old boy with Lipoma of corpus callosum. Coronal T1-weighted MR image shows large well-defined homogeneous midline mass lesion in region of corpus callosum with characteristic bright signal of Lipoma. Note associated dysgenesis of corpus callosum.

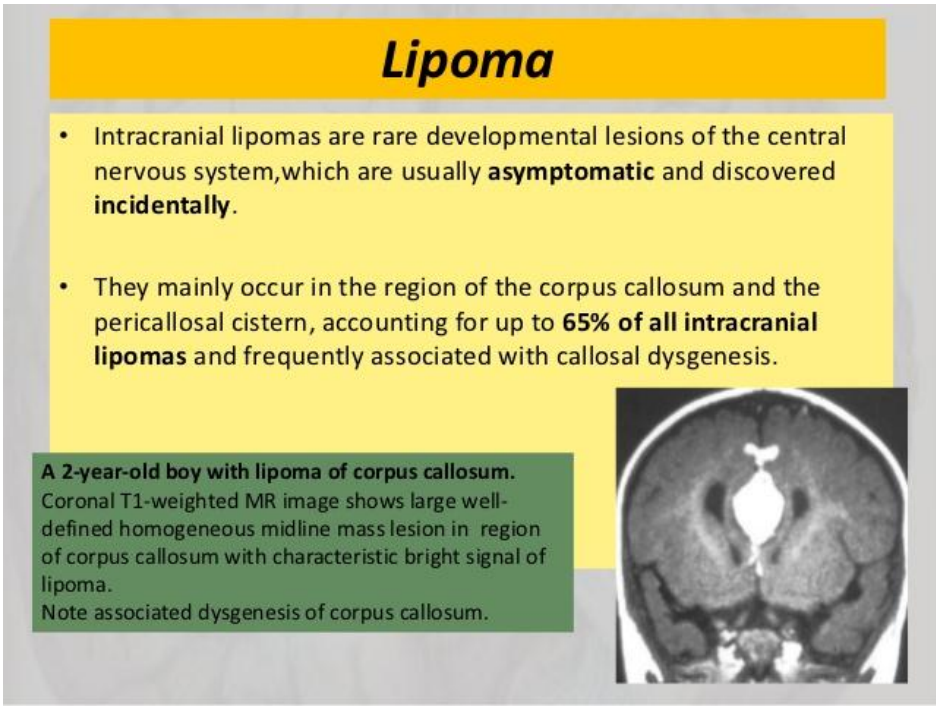

Fig (2-22) Lipoma of Corpus callosum

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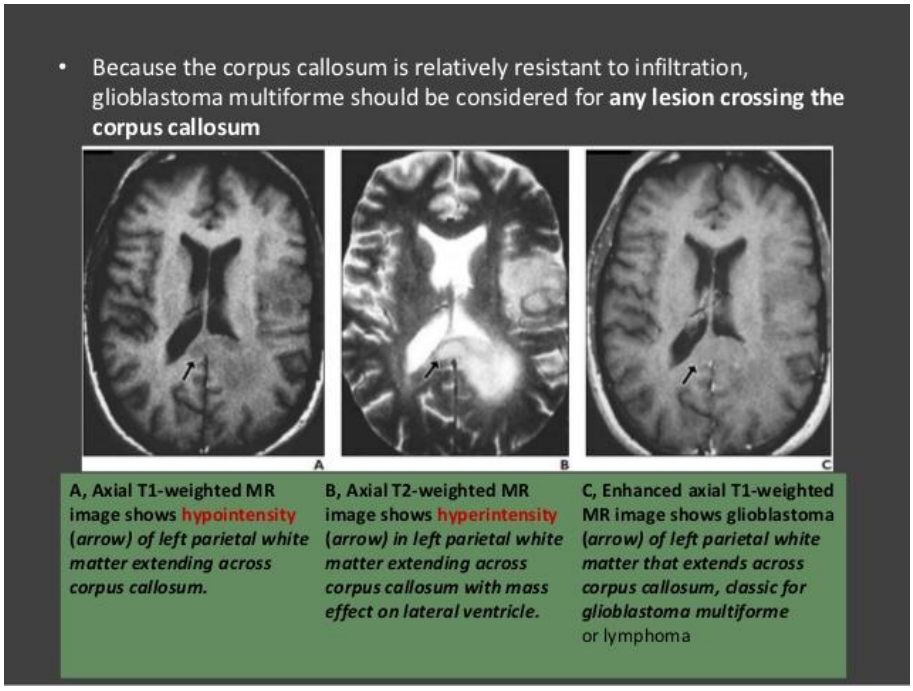
Glioblastoma Multiforme is an extremely aggressive diffuse astrocytic tumor commonly found in the upratentorial white matter of the cerebral hemispheres.It is the most common primary brain tumor in adults, accounting for 25% of all cases. Glioblastomas most commonly spread via direct extension along white matter tracts, including the corpus callosum, although hematogenous, subependymal, and cerebrospinal fluid spread can also be seen. When the corpus callosum is affected, Glioblastoma Multiforme commonly displays a characteristic bihemispheric involvement, resulting in a classic butterfly pattern. Because the corpus callosum is relatively resistant to infiltration, Glioblastoma Multiforme should be considered for any lesion crossing the corpus callosum. **A**, Axial T1-weighted MRI. **B**, Axial T2-weighted MRI. **C**, Enhanced axial T1-weighted image shows hypo intensity image shows hyper intensity MR image shows Glioblastoma of the left parietal white matter extending across matter that extends across corpus callosum. Corpus callosum with mass corpus callosum, classic for effect on lateral ventricle. This may be Glioblastoma Multiforme or lymphoma.



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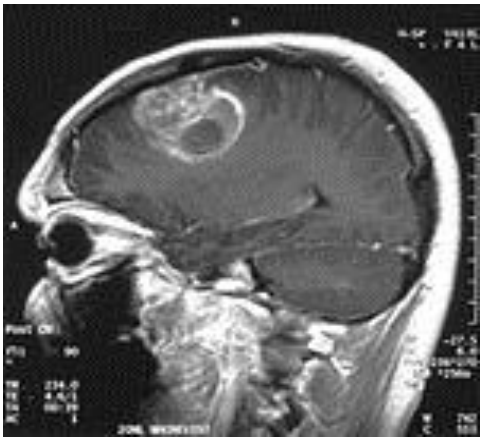

Fig 2-23: Sagittal MRI with contrast of a Glioblastoma WHO grade IV in a 15-year-old boy.

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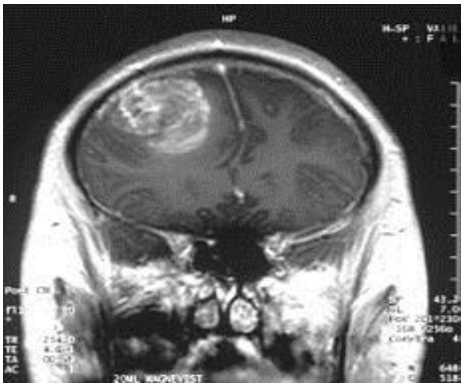

Fig 2-24 Coronal MRI with contrast of a Glioblastoma WHO grade IV in a 15-year-old boy

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Primary central nervous system lymphomas are rare aggressive neoplasms of the brain, accounting for less than 2% of malignant primary brain tumors. They are almost always of the B-cell non-Hodgkin's type. Common locations include the corpus callosum, deep gray matter structures, and the periventricular region. Lymphomas differ from Glioblastoma Multiforme because they usually have

less peritumoral edema, are more commonly multiple, are less commonly necrotic, are highly radiosensitive, and fre- quently temporarily respond dramatically to steroid administration producing “vanishing lesions.”

Juvenile Pilocytic Astrocytoma is a distinct low-grade variant of astrocytoma. They are usually well-circumscribed unencapsulated masses, with frequent cyst formation, either microscopic or macroscopic. Most lesions commonly involve the cerebellar vermis, cerebellar hemispheres, optic chiasm, hypothalamus, or floor of the third ventricle. The corpus callosum is an uncommon location. The solid portion of the tumor usually enhances, in contrast to most low-grade infiltrative astrocytomas, which tend not to enhance astrocytoma. A, Sagittal T1-weighted MRI shows well- circumscribed hypointense lesion in body of corpus callosum. B, Axial T2-weighted MRI shows that lesion is hyper intense. C, Enhanced coronal T1 - weighted MR image shows marked contrast enhancement of lesion.

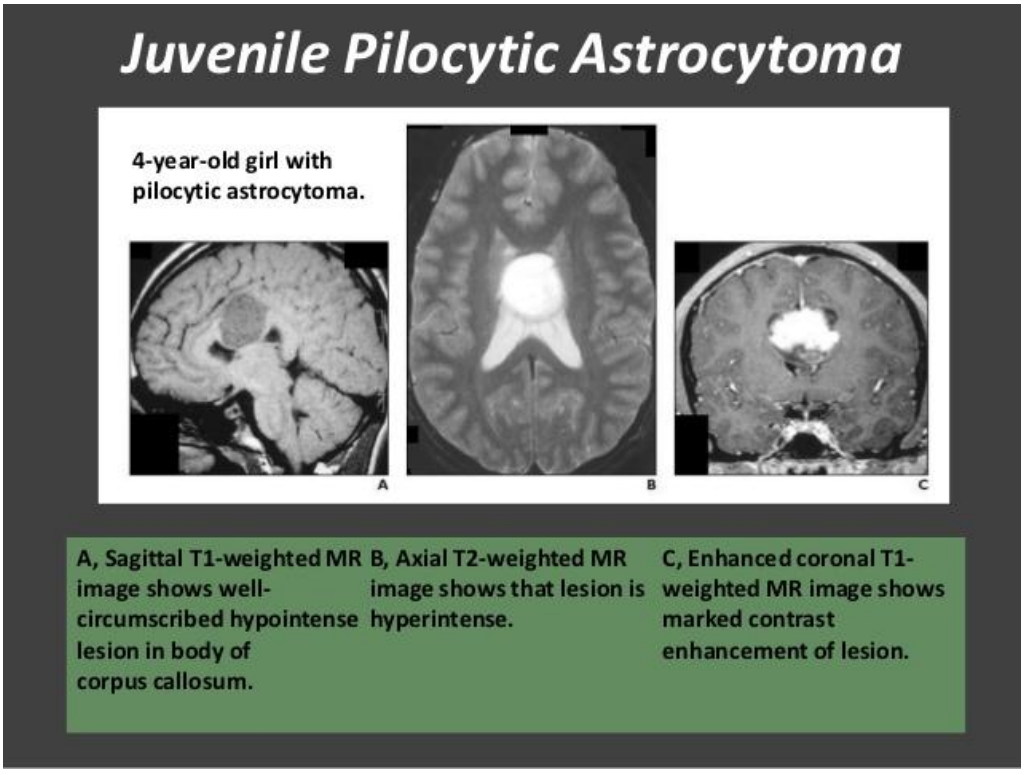

Fig 2-25 Coronal MRI contrast of a Glioblastoma WHO grade IV in a 4-year-old Girls with Pilocytic Astrocytoma

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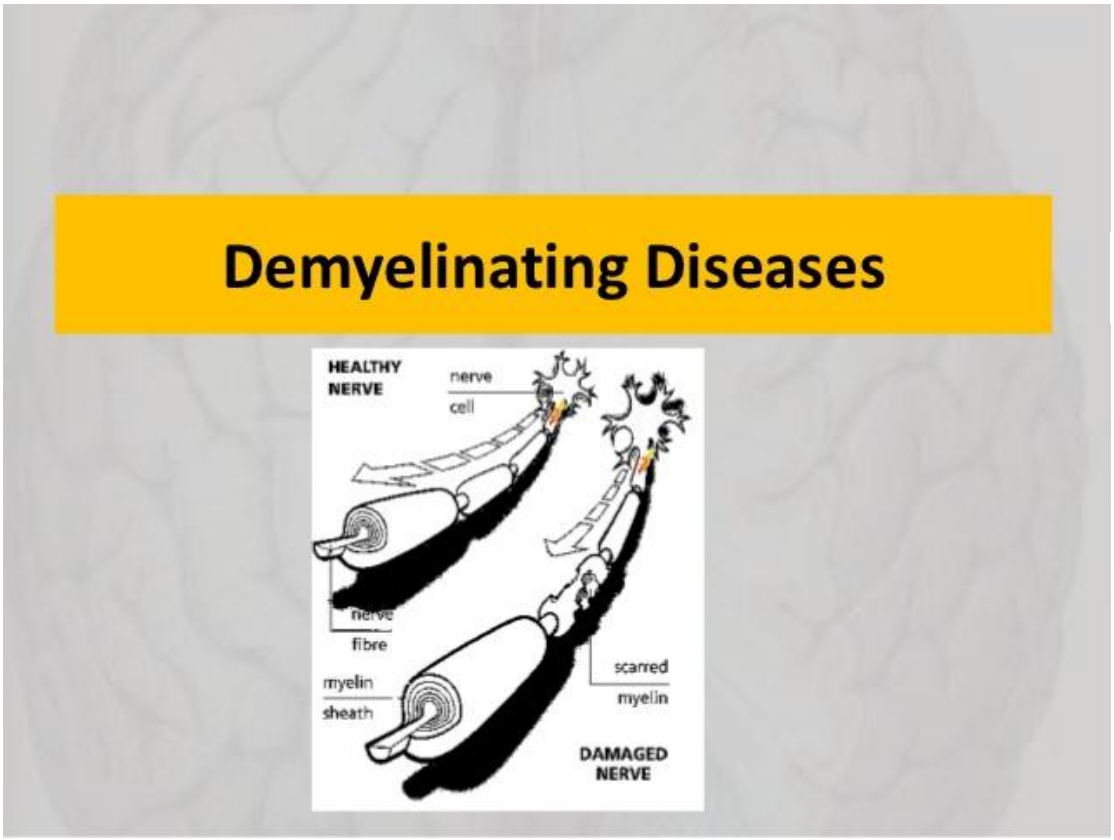
Demyelinating Diseases : Multiple sclerosis is a demyelinating disease of unknown cause that more commonly affects young women. Lesions characteristically involve the periventricular white matter, internal capsule, corpus callosum, and pons, although plaques can be found anywhere in the white matter and less commonly even in gray matter. The lesions of the corpus callosum can be focal or confluent nodular lesions and tend to affect the callosal–septal interface, which is the central inferior aspect of the corpus callosum. On MR imaging, the prevalence of lesions in the corpus callosum has been reported to be up to 93% in the radiology literature. Atrophy of the corpus callosum can coexist in long-standing multiple sclerosis, making the diagnosis of corpus callosum lesions difficult. Enhancement is common in the acute stage. Differentiation should be made from ischemia, trauma, and other demyelinating processes on the basis of morphology, location, and the presence of concurrent multiple sclerosis plaques in the periventricular region .



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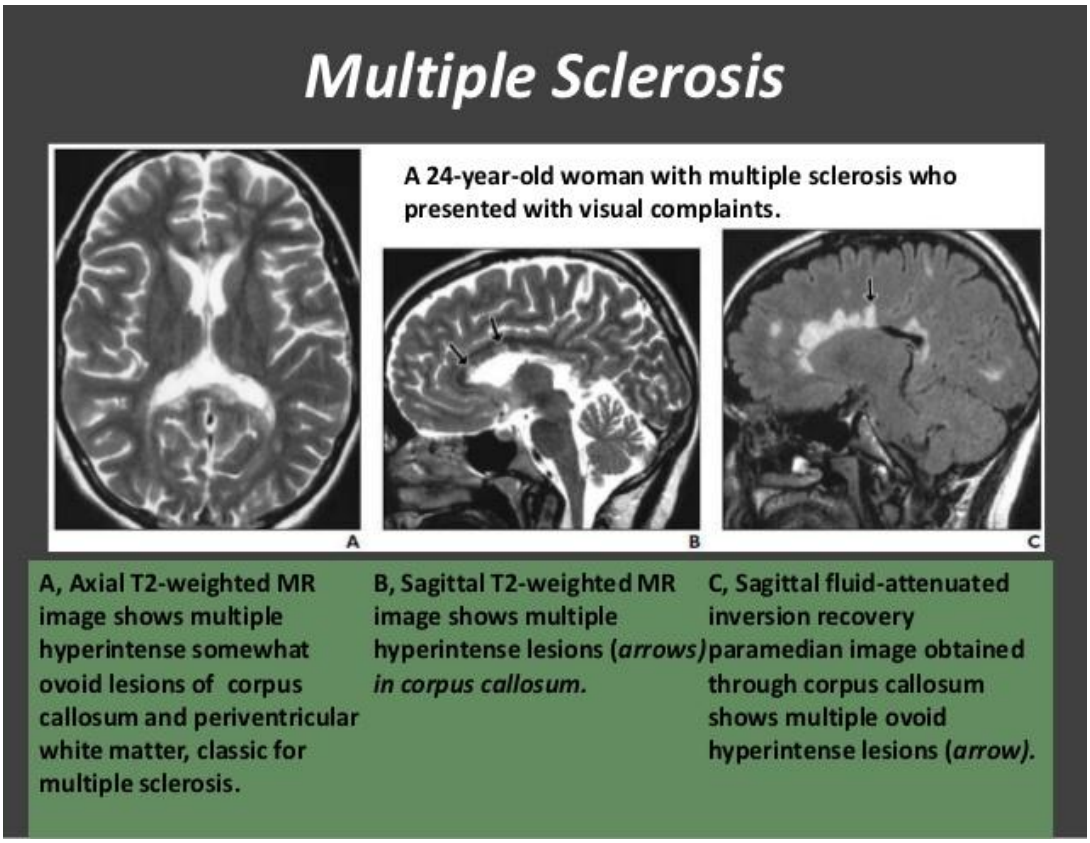

B

Fig 2-26 Demyelinating Diseases , Multiple Sclerosis

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Progressive Multifocal Leukoencephalopathy : Progressive multifocal leukoencephalopathy is an uncommon progressive fatal demyelinating disease that affects immunocompromised patients.The cause is a papovavirus , the Creutzfeldt-Jakob virus. The lesions are usually multifocal and asymmetric, most commonly affecting the subcortical white matter and corpus callosum. In the corpus callosum, focal lesions can occur that enlarge and become confluent as the disease progresses. Progressive multifocal leukoencephalopathy should be considered in the differential diagnosis of space-occupying lesions in HIV patients.The lack of enhancement and mass effect can act as features differentiating this entity from others such as lymphoma or Glioblastoma

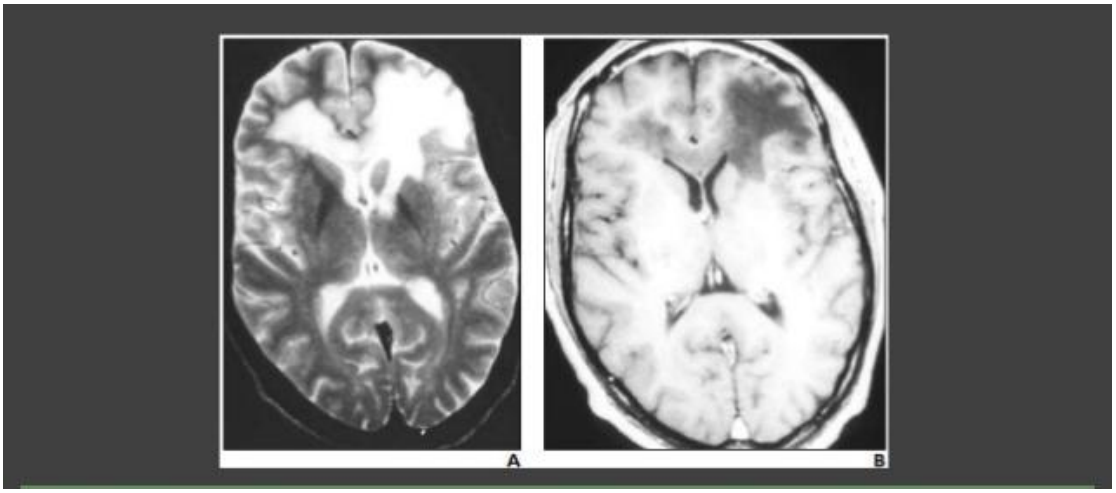

Fig 2-27 a 44-years old man with HIV

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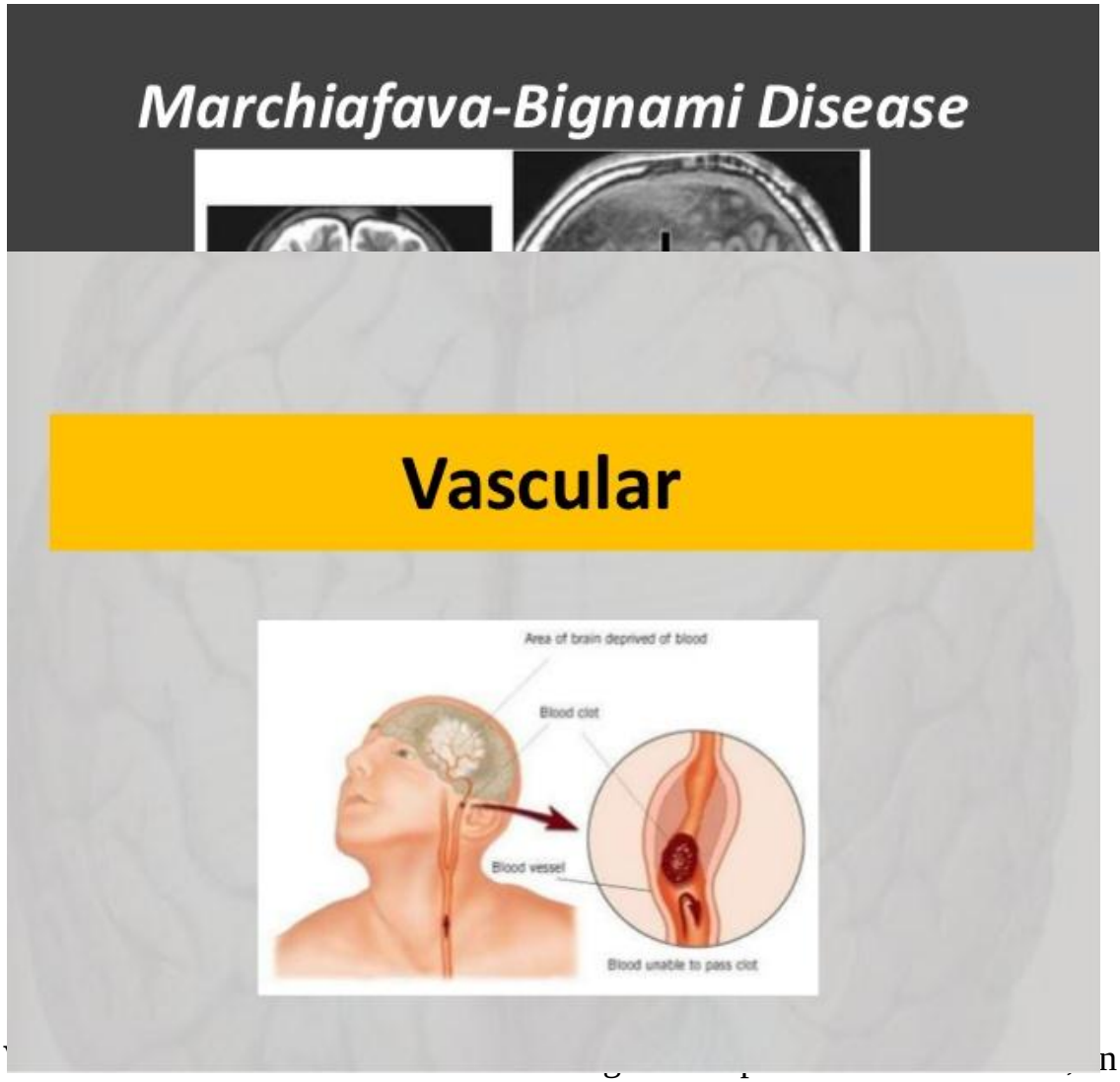
Marchiafava-Bignami Disease: Marchiafava-Bignami disease is a rare demyelinating neurologic disorder, primarily affecting the corpus callosum. It was first described in Italian wine drinkers and is thought to be due to chronic and massive alcohol use. The central layers of the corpus callosum are affected, with sparing of the dorsal and ventral layers (sandwich sign). The disease can follow one of three clinical courses, a fulminate, acute form or subacute and chronic forms. Acute affect the genu and the splenium, chronic affect the body. Marchiafava-Bignami Disease A, Axial T2-weighted MR image shows signal B, Sagittal T1-weighted MR image shows corpusabnormality of corpus callosum and callosum atrophy (short arrow), which isperiventricular white matter. Characteristic of chronic form. Involvement of central layers of corpus callosum, indicated by hypointensity, with sparing of dorsal and ventral layers results in the sandwich sign (long arrow).



n part because the corpus callosum is a dense white matter tract and therefore is less sensitive to ischemic injury than gray matter. The anterior and posterior cerebral arteries provide the major blood supply of the corpus callosum via the pericallosal artery and small penetrating vessels that run perpendicular to the parent artery.

On MR imaging, infarcts have the same characteristics as strokes elsewhere, with similar enhancement patterns. Differentiation of lacunar infarcts from other entities such as trauma and demyelinating processes can be made by the presence of concurrent infarcts in characteristic sites (centrum semiovale, basal ganglia). With large-vessel ischemic events, the corpus callosum is usually involved as part of a large vascular distribution .Infarction 59-year-old man

with infarct who presented with confusion 2 weeks later 6 weeks after initial onset : well-defined that lesion (arrow) is presentation shows lesion of corpus smaller and has that lesion (arrow) iscallosum genu. decreased in signal.

Arteriovenous malformations of the corpus callosum comprise 9–11% of all cerebral arteriovenous malformations. Clinically, 84% of patients with these malformations present with intracranial hemorrhage, most with intraventricular hemorrhage. Most are supplied by both the anterior and posterior cerebral arteries, and many have a bilateral blood supply. Drainage is mainly into the internal cerebral vein or interhemispheric superficial veins. The MR imaging characteristics are those of arteriovenous malformations elsewhere, with serpentine flow voids noted through the corpus callosum and the ventricle and frequently with evidence of intraventricular hemorrhage. Arteriovenous Malformations A, Sagittal T1-weighted MR image shows B, Axial T2-weighted MR image shows hemorrhage (arrows) and multiple flow hyperintense lesion (arrow) with flow voids. voids in corpus callosum.

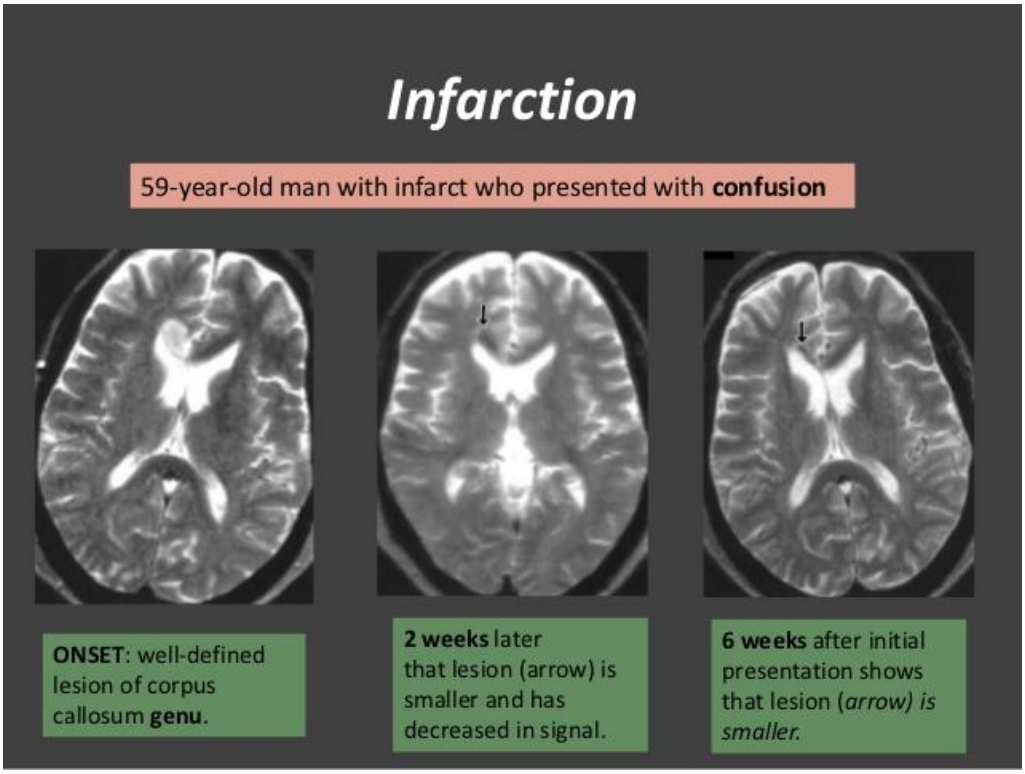


Fig 2-29 Infraction 59- years old a man with infract

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Trauma: The classic triad of diffuse axonal injury is that of diffuse damage to axons at 1. The gray–white matter interface of the cerebral hemispheres, 2. The dorsolateral aspect of the rostral brainstem, 3. The corpus callosum. The callosal lesions most commonly involve the splenium, are usually eccentric in location, and can involve a focal part or the full thickness of the corpus callosum. On MR imaging, spin echo T2-weighted images and FLAIR sequences during the sagittal plane are most sensitive in detecting small nonhemorrhagic lesions. Hemorrhagic lesions are best seen on T2- weighted images during the first 4 days after injury and, after 4 days, are better seen on T1- weighted images. Differentiation from other lesions such as ischemia should be made on the basis of history and the location of the lesions in the corpus callosum 20-year-old man with diffuse axonal injury 1 week after motor vehicle crash. A, Sagittal T1-weighted MR image shows nonhemorrhagic hypointense lesion (arrow) of corpus callosum. B, Axial proton density–weighted MR image shows hyperintense lesion of corpus callosum. C, Sagittal T1-weighted MR image on follow-up examination 10 days after B shows hemorrhagic lesion of corpus callosum. D, Enhanced coronal T1-weighted MR image on follow-up examination 10 days after B shows hemorrhagic lesion of corpus callosum, with classic shearing-type lesion also seen at gray, white junction, both indicative of diffuse axonal injury.

Miscellaneous Lesions in the corpus callosum, both diffuse and focal, have been described in patients with long-standing hydrocephalus after shunting. Callosal lesions and tectal neoplasms producing hydrocephalus have been seen in patients with aqueductal stenosis. Patients with these lesions were thought to have long-standing hydrocephalus before ventricular decompression. The exact mechanism responsible for the production of these callosal lesions is unknown, although they may be the result of ischemia with subsequent demyelination caused by prolonged severe stretching of the corpus callosum from ventriculomegaly and subsequent rapid decompression of the ventricles.

45-year-old man with cystic lesions associated with long-standing hydrocephalus, with multiple prior shunt revisions. Patient is asymptomatic other than for headaches, which are probably due to mild hydrocephalus. A, Sagittal T1-weighted MR image B, Axial T2-weighted MR image shows well-defined shows abnormal signal cystic lesions (arrows) of corpus (arrow) throughout corpus callosum , which has persisted for many years.

Disconnection syndromes: After anterior cerebral artery occlusion with anterior callosal infarction, the right hemisphere is deprived of verbal information; a left-hand apraxia is seen, the patient cannot name unseen objects placed in the left hand. Reciprocally, the right hand shows constructional apraxia. This is termed the anterior disconnection syndrome. After occlusion of the left posterior cerebral artery with infarction of the left occipital lobe and the splenium (posterior portion) of corpus callosum, the language cortices of the left hemisphere lose access to visual information: The left visual cortex is damaged, as are the projections from the right visual cortex, which cross in the splenium. – Thus, reading becomes impossible, although other language functions are unaffected the syndrome of alexia without agraphia. Disconnection syndromes Corpus callosotomy, which aims to prevent the interhemispheric spread of seizures, results in a unique, transient disconnection syndrome of Mutism, Apathy, Agnosia, Apraxia, Difficulty naming, Writing with the nondominant hand. Gerstmann syndrome is characterized by four primary symptoms: Dysgraphia/agraphia: deficiency in the ability to write Dyscalculia/acalculia: difficulty in learning or comprehending mathematics Finger agnosia: inability to distinguish the fingers on the hand Left-right disorientation .This disorder is often associated with brain lesions in the dominant (usually left) hemisphere

Lesions in psychiatric diseases ADHD, (Dyslexia): anterior part of corpus callosum (Autism) posterior part of corpus callosum OCD . Rostrum OrbitoFrontal Cortex In childhood sexual abuse between 9 to 10 years and 14

to 16 years was associated with maximal affects on corpus callosum and frontal cortex, respectively. PTSD smaller intracranial volume and corpus callosum area. Lesions in Schizophrenia .Several observations are seen with the studies on the corpus callosum in schizophrenia 1. Callosal pruning and myelination as well as interhemispheric coherence continue to develop into early adulthood, a factor that may be relevant to age of onset in schizophrenia 2. Impairments in callosal transfer have been reported in patients, implicating alterations in callosal connectivity; 3. Structural alterations in asymmetric perisylvian regions linked by the callosum have been reported 4. Callosal myelination begins prenatally and is susceptible to malnutrition, asphyxia and toxins of infectious origin; also, these same events are linked with aberrant neuro-developmental events in schizophrenia 5. The corpus callosum forms the roof of the superior horns of the lateral ventricles, which are enlarged in schizophrenic patients. In spite of evidence linking callosal abnormality to schizophrenia, imaging studies assessing alterations in callosal morphometry as well as in other cortical and subcortical structures have produced surprisingly mixed results.

2-5 imaging of corpus callosum

2-5-1 Ultrasonography of the corpus callosum:

2-5-1-1 Background:

The corpus callosum (CC) is the largest commissural pathway connecting the two cerebral hemispheres. It develops relatively late during cerebral ontogenesis, not assuming its definitive shape until 20 weeks of gestation, and continues to grow well after delivery [Malinger G, Pilu G. *Sonography of the fetal central nervous system*, 2009]. Therefore, a proper prenatal sonographic evaluation can be performed only after 20 weeks.

Ideally, the CC is assessed on ultrasound by direct visualization. It is a thin band of white-matter fibers and is not depicted using a standard axial plane. It can be seen in the coronal plane, but is only demonstrated in its entire length by using mid-sagittal views, that represent the gold standard for diagnosing abnormalities

of this structure. Visualization of coronal and mid-sagittal planes requires technical skill, and is not recommended in standard examinations of low-risk pregnant patients. Reference ranges of fetal CC dimensions have been published and can be used to assess normal and deviant development.

There is a general consensus that diagnosing CC abnormalities is difficult. In standard examinations, absence of the CC may be detected because of either indirect cerebral findings, such as ventriculomegaly, absence of the cavum septi pellucidi or widening of the interhemispheric fissure, or associated extracranial findings. The sensitivity of screening exams is, however, unknown, but is probably limited. The interested reader is referred to a recent comprehensive review.

2-5-1-2 Practical points:

Adequate demonstration of the CC in the second trimester can often be achieved by standard transabdominal ultrasonography. However, in vertex fetal presentation, a transvaginal scan with a high-frequency transducer provides better resolution. In breech presentation, a transfundal approach is the only possibility. In coronal and mid-sagittal views, the CC appears as a thin anechoic space, bordered superiorly and inferiorly by echogenic lines. The mid-sagittal view is certainly the most useful view. The ultrasound beam crosses the large midline acoustic window, formed from anterior to posterior by the frontal or metopic suture, the bregmatic fontanel and the sagittal suture, and this allows good resolution of the brain structures of the midline. For a proper assessment of the CC, good-quality two-dimensional (2D) gray-scale imaging is essential and is generally sufficient. Color Doppler may, however, play a complementary role, particularly in early gestation. In cases of difficult visualization, three-dimensional (3D) ultrasound may be helpful.

2-5-1-3 Two-dimensional ultrasound:

Two practical approaches may be of help in order to achieve adequate visualization of the CC: This approach is usually feasible transabdominally.

- Obtain a standard mid-sagittal view of the fetal profile (Figure 2-5-1 a).
- Angulate the transducer in order to use the acoustic window of the frontal suture and the anterior fontanel, thus demonstrating the CC (Figure 2-5-1 b).
- Fine side-to-side movements may be needed in order to achieve an ideal image of the CC.

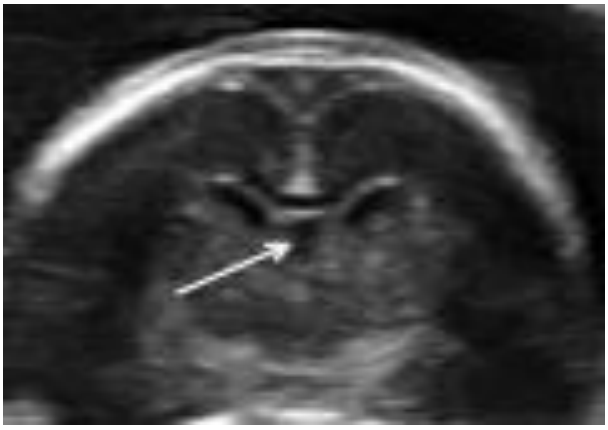

Figure 2-30. Coronal approach. Coronal section of anterior horns of lateral ventricles and cavum septi pellucidi (arrow), with the latter oriented strictly vertically. The transducer is then rotated 90°, obtaining a midline brain section and visualizing the corpus callosum.

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This approach is feasible both transabdominally and transvaginally.

- From a coronal section through the anterior fontanel, obtain a coronal section of the anterior horns of the lateral ventricles and the cavum septi pellucidi. The latter should be oriented as close to vertically as possible, with the anterior horns on the same horizontal level (Figure 2-5- 2).
- Rotate the transducer 90°, obtaining the mid-sagittal plane of the fetal brain.
- Fine side-to-side movements may be needed in order to achieve an ideal image of the CC.

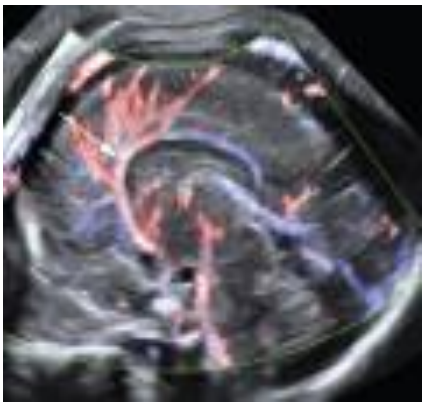

Figure 2-31. Color Doppler demonstration of cerebral circulation (mid-sagittal view) in a normal fetus at 20 weeks' gestation: the pericallosal artery (arrow) highlights the corpus callosum.

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Color Doppler visualization of the pericallosal artery (Figure 2-5-3)

Once the mid-sagittal plane of the fetal brain has been obtained, applying color Doppler will demonstrate the course of the pericallosal artery. This may be helpful, particularly in early gestation and in dubious cases. Proper adjustment of pulse repetition frequency (main cerebral arteries have velocities in the range of 20–40 cm/s during intrauterine life) and signal persistence enhances visualization of small vessels.

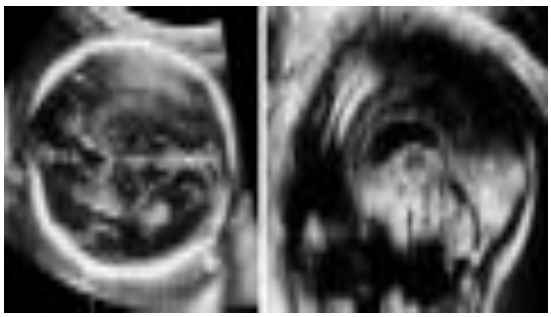

Figure 2-32. Three-dimensional imaging. Axial view at the level of the biparietal diameter (left) and reconstructed orthogonal plane showing the mid-sagittal view (right).

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Three-dimensional assessment of the corpus callosum (Figure 2-32)

The main advantage of 3D imaging is the possibility of obtaining a ‘virtual’ mid-sagittal plane reconstructed from an axial approach, thus avoiding the need

to align the transducer with the midline cranial sutures. However, direct 2D visualization allows images of much superior quality. Furthermore, 3D ultrasound only allows visualization of the external contour of the CC and therefore does not allow identification of abnormalities of CC thickness (Malinger, *et al 2006*).

This approach is usually feasible transabdominally.

- Obtain a standard axial view of the head at the level of the biparietal diameter, with the intersection point of the planes positioned in the cavum septi pellucidi.
- Activate the volume contrast imaging (VCI) 3D mode to display the B- and C-planes of the fetal head.
- The CC should be visible in the C- or orthogonal plane which displays the reconstructed mid-sagittal view of the fetal brain.
- The intersection point may need to be moved towards either wall of the cavum septi pellucidi to optimize the image of the CC.

2-5-2 CT/ MRI of the corpus callosum:

The usual morphological MRI sequences include a sagittal T_1 or T_2 (fluid-attenuated inversion recovery ((FLAIR)) weighted plane, as well as DTI reformatting images for an optimal study of the CC, were implemented.

MRI is the modality of choice for the study of the CC. As a densely packed white matter structure, the CC is visualised with a high signal in T_1 weighted imaging (WI) and a low signal in T_2 images. Sagittal plane images provide an overview of the structural integrity and extent of development of the CC, whereas in coronal images we can better evaluate its relationship to the cerebral hemispheres.

Complete assessment of CC pathologies is facilitated by the acquisition of the following sequences: T_1 WI, fast spin-echo (FSE) T_2 WI, as well as FLAIR sequences and volume acquisition sequences with high resolution. New techniques such as DTI have further expanded our capability to visualise the

organisation and orientation of the axonal pathways of the CC with tractography and quantitatively with the use of anisotropic indices of diffusion such as fraction anisotropy (FA) maps, permitting a better comprehension and analysis of the CC microstructure.

The use of susceptibility-sensitive sequences (susceptibility-weighting imaging ((SWI)) plays an important role in the assessment of traumatic injury and other pathologies of the brain resulting in the deposition of blood products or calcium, including pathologies affecting the CC. Vascular ((three-dimensional (3D) time-of-flight (TOF)) sequences, on the other hand, are essential in cases of ischaemic or haemorrhagic lesions.

Images after contrast media enhancement are not necessary for the study of malformations or traumatic pathologies of the CC.

If a viral infection is suspected, the MRI study, including perfusion sequences, should be repeated within 48–72 h after the initial study in order to confirm the diagnosis.

CT imaging is important for the diagnosis of CC lipomas and other pathologies with calcium deposition and can also be useful for the diagnosis of tumour, haemorrhage or infarction; CT angiography is essential for the diagnosis of aneurysms responsible for haematomas, more commonly situated in the anterior part of the CC.

2-6 Previous Studies

Study (1) : Measurement of the corpus callosum using magnetic resonance imaging in the north of iran. (Mohammadi MR[1] et al 2011 . Iran)

This study was done to measure the size of CC and to identify its gender- and age-related differences in the North of Iran

The size of CC on midsagittal section was measured in 100 (45 males, 55 females) normal subjects using magnetic resonance imaging (MRI) admitted to the Kowsar MRI center in Gorgan-Northern Iran. Longitudinal and vertical dimensions of the CC, longitudinal and vertical lengths of the brain and the length of genu and splenium were measured. Data were analyzed by student's unpaired t test, ANOVA and regression analysis.

The anteroposterior length and vertical dimension of the CC, the length of genu and splenium were larger in males than in females, but these differences were not significant. The anteroposterior and vertical lengths of the brain were significantly larger in males than in females ($P < 0.05$). The length of CC increased with age and regression equations for predicting age were derived from the length of the CC. There was also a positive significant correlation between the anteroposterior length of the CC and the length of the brain and vertical dimension of the CC

Study (2)

Sex differences in corpus callosum size: relationship to age and intracranial size

(Sullivan,Margaret J et al 2001. USA)

Report this study MRI to measure the body callosum in 51 healthy male. And 41 female in good health, stretched from the age of 22 years old to 71 years old، The results of the measurement of body size callosum in males larger than females

Study (3)

MR imaging of the corpus callosum: normal and pathologic findings and correlation with CT. By : (Reinarz et al -1988).

The MR appearance of the corpus callosum was investigated in 80 normal volunteers. Normal variations in appearance were recorded with regard to age, gender, and handedness. The MR studies of 47 patients with a wide spectrum of callosal disease were also reviewed. Abnormalities included trauma, neoplasia, congenital abnormalities, vascular lesions, and demyelinating and inflammatory conditions. The information provided by MR was compared with that obtained from other radiographic examinations, particularly CT and angiography. In all cases MR provided as much, and frequently more, information than was obtained by other imaging techniques. We believe that MR should be the primary imaging technique for the evaluation of corpus callosal disease.

Study (4)

The role of the corpus callosum in interhemispheric transfer of information: excitation or inhibition?

(Bloom JS, Hynd GW,2009)

The corpus callosum is the major neural pathway that connects homologous cortical areas of the two cerebral hemispheres. The nature of how that interhemispheric connection is manifested is the topic of this review; specifically, does the corpus callosum serve to communicate an inhibitory or excitatory influence on the contralateral hemisphere? Several studies take the position that the corpus callosum provides the pathway through which a hemisphere or cortical area can inhibit the other hemisphere or homologous cortical area in order to facilitate optimal functional capacity. Other studies suggest that the corpus callosum integrates information across cerebral hemispheres and thus serves an excitatory function in interhemispheric communication. This review examines these two contrasting theories of interhemispheric communication. Studies of callosotomies, callosal agenesis,

language disorders, theories of lateralization and hemispheric asymmetry, and comparative research are critically considered. The available research, no matter how limited, primarily supports the notion that the corpus callosum serves a predominantly excitatory function. There is evidence, however, to support both theories and the possibility remains that the corpus callosum can serve both an inhibitory and excitatory influence on the contralateral hemisphere.

Study (5)

Corpus callosum: normal imaging appearance, variants and pathologic conditions.

(Battal ,*et al* 2010)

Various types of lesions can occur within the corpus callosum (CC) which is a white matter tract communicating corresponding regions of the cerebral hemispheres. Magnetic resonance imaging is the modality of choice for the evaluation of the CC. In addition, diffusion weighted imaging and diffusion tensor imaging can provide additional information about the CC. The aim of this study is to illustrate the imaging features of the corpus callosum and its pathologies.

Study (6)

Dissociation between corpus callosum atrophy and white matter pathology in Alzheimer's disease.

(Teipel *et al* , 2003)

OBJECTIVE*:*

To determine whether the size of the corpus callosum is related to the extent of white matter pathology in patients with AD and age-matched healthy control subjects.

METHODS*:*

White matter hyperintensity load and corpus callosum size were compared between 20 clinically diagnosed AD patients and 21 age-matched healthy control subjects. We investigated the effect of age and disease severity on

corpus callosum size and white matter hyperintensity, in addition to the relation between corpus callosum areas and white matter hyperintensity load.

RESULTS*:*

We found significant regional atrophy of the corpus callosum in AD when compared with control subjects, although the groups did not differ in their white matter hyperintensity load. We further showed a region-specific correlation between corpus callosum size and white matter hyperintensity in the control group but not in AD patients. In the AD group, corpus callosum size correlated with age and dementia severity, whereas white matter hyperintensity correlated only with age.

CONCLUSION*:*

Corpus callosum atrophy in AD can occur independent of white matter degeneration, likely reflecting specific AD pathology in projecting neurons.

CHAPTER THREE

Materials and Methods

3-1 Materials & tools:

3-1-1 Study population:

3-1-2 Inclusion criteria:

3-1-3 Exclusion criteria:

3-1 Machine used:

The study was conducted during the period from August 2013 up to February 2015 at Modern Medical Center, Khartoum-Sudan.MR examinations were acquired on MRI Siemens Avanto 2010, 1.5 Tesla super-conducted magnet, using T1-weighted, TR 450, Echo Time of 8.70, (multisection sagittal conventional spin-echo sequence with a 5-mm section thickness, a 1.5-mm gap, and a 256 X256 matrix, FOV 100.

3-2 Technique and method of measurements

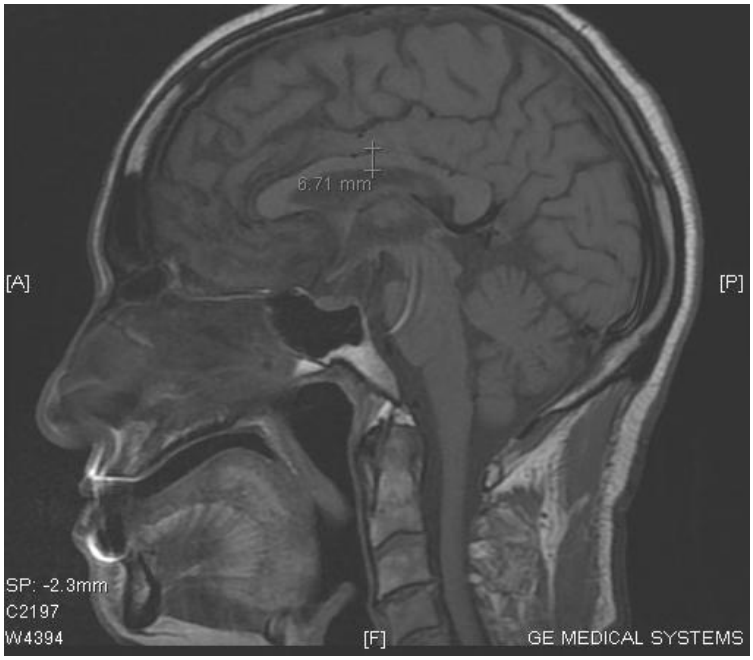
A total of 100 Sudanese adults were included (50 were males and 50were females) .All underwent MR examinations; Mean ages were 34.64±20.61.

For each study, the patients lied supine on the examination couch with their head within the head coil .The head is adjusted so that the inter pupillary line is parallel to the couch and the head is straight. The patients were positioned so that the longitudinal alignment light lies in the midline and the horizontal alignment light passes through the nasion, straps and foam pads are used for immobilization. the sagittal image closest to the median sagital plane was used to measure the (CC) antro-posterior distance (mm), genu thickness(mm), body thickness (mm), splenum thickness (mm)and(CCI) . Patients with brain diseases were excluded.

Figures (Gupta B, 2008) showed the points of measurements .Corpus callosum index (CCI) was obtained on a midsagital

T1weighted image, drawing a straight line at greatest anteroposterior diameter of (CC) and a perpendicular at its midline, owing to points Aa, Bb and Cc. (CCI) was found for each cases, from the calculated measurements by the formula***:- CCI= (Aa + Bb+ Cc) / Ac*.**

(3.1) Material



(3.1) Material:

3-3 Data analyses

All data were presented as mean± SD values. Data were analyzed by an independent t test and by correlation analysis with the use of the SPSS (Inc., Chicago, Illinois version 16). A value of P□0.05 was considered significant.

3-4 Ethical Consideration:

- No identification or individual details were published.
- No information or patient details will be disclosed or used for reasons other than the study.

Chapter four
Results

Table (4-1): Distribution frequency and percentages according to Age

Age	*Frequency*	*Percent(%)*
<10	6	6.0
11-20	28	28.0
21-30	19	19.0
31-40	13	13.0
41-50	12	12.0
>50	22	22.0
Total	***100***	***100()***

Mean age = 34.64 ± 20.62

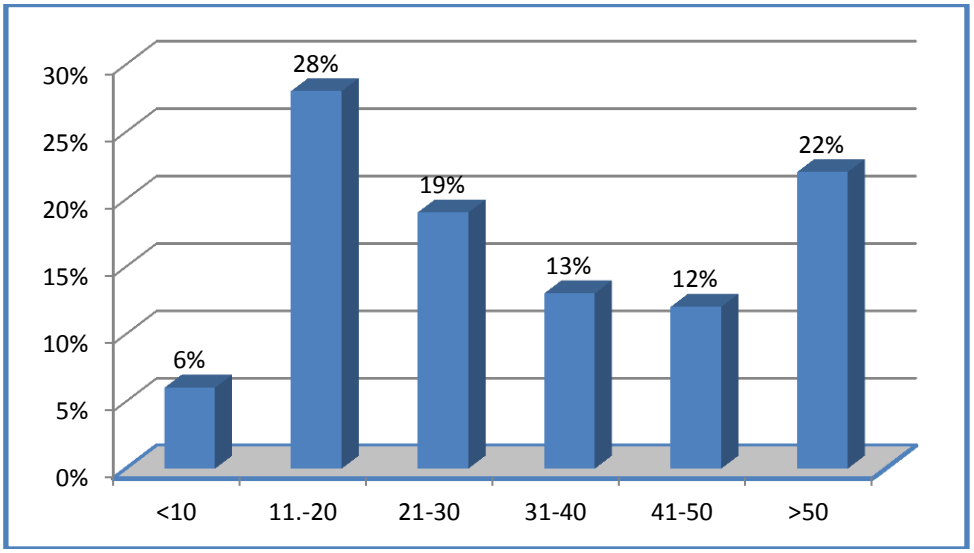


Fig (4-1) : Distribution frequency and percentages according to Age Gender

Table (4.2) Distribution of ages and CCI and thickness genu and thickness body and thickness splenum

	Age	Cc length	Thickness genu Aa	Thickness body Bb	Thickness splenum cc	Cci
Mean	34.6400	75.7533	17.5447	6.8971	16.7647	.5334
Std. Deviation	20.61603	7.13869	2.13980	1.08507	2.45778	.08942

Table (4-3) : Distribution frequency and percentages according to Gender

	Frequency	***Percent(%)***
Male	50	50.0
Female	50	50.0
Total	***100***	***100()***

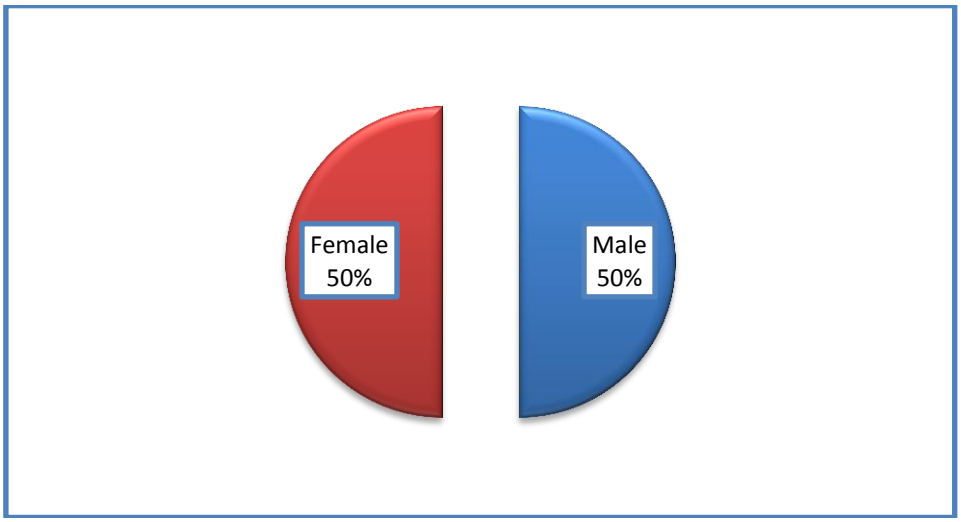


Fig (4-2) by graph show gender details

Table (4.4) Results of male & Female (mean + standard deviation)

Mean	**Brain AP sagtal**	**P- value**
F	**156.4882**	**0.964**
M	**156.4128**	
Total	**156.4505**	
Mean	**Brain AP axial**	**P- value**
F	**161.3586**	**0.440**
M	**162.6688**	
Total	**162.0137**	
Mean	**Brain Transverse axial**	**P- value**
F	**118.6380**	**.046**
M	**121.0614**	
Total	**119.8497**	

At P< 0.005

Table (4-5a) Cc length, Thinkness genu Aa, Thickness body Bb, Thickness splenum cc, CCI table for variables distribution according to age

Descriptives							
		N	Mean	Std. Deviation	Minimum	Maximum	P -value
Cc length	<10	6	62.3417	5.33209	55.38	67.95	.000
	11-20	28	76.4650	4.96783	66.99	86.27	
	21-30	19	72.8816	8.41926	46.90	82.77	
	31-40	13	75.3285	4.41351	68.46	82.93	
	41-50	12	80.7308	6.34523	74.71	93.74	
	>50	22	78.5214	5.19045	68.06	89.73	
	Total	100	75.7533	7.13869	46.90	93.74	
Thickness genu Aa	<10	6	15.0950	1.21535	13.18	16.17	.013
	11-20	28	17.3911	1.69320	14.64	19.74	
	21-30	19	18.2016	2.01853	15.10	21.52	
	31-40	13	18.4354	2.16693	15.06	21.77	
	41-50	12	18.0308	2.28717	14.60	21.19	
	>50	22	17.0495	2.36910	12.95	22.45	
	Total	100	17.5447	2.13980	12.95	22.45	
Thickness body Bb	<10	6	5.9500	.82808	4.89	6.83	.005
	11-20	28	6.6546	1.00530	4.24	7.81	
	21-30	19	7.4300	1.09337	5.16	9.69	
	31-40	13	7.2785	.74178	6.21	8.52	
	41-50	12	7.2975	1.09447	5.47	8.52	
	>50	22	6.5600	1.10860	4.44	9.44	
	Total	100	6.8971	1.08507	4.24	9.69	
Thickness splenum cc	<10	6	12.0967	4.02092	4.78	15.48	.000
	11-20	28	16.4471	1.64376	13.52	20.72	
	21-30	19	16.9089	2.44413	8.88	20.40	
	31-40	13	17.3400	1.50774	15.14	19.91	
	41-50	12	18.2442	2.82233	15.37	23.46	
	>50	22	17.1705	1.59846	14.60	22.09	
	Total	100	16.7647	2.45778	4.78	23.46	
CCI	<10	6	.5585	.03392	.51	.59	.028
	11-20	28	.5312	.03544	.45	.59	
	21-30	19	.5707	.03455	.51	.64	
	31-40	13	.5709	.04779	.48	.63	
	41-50	12	.4939	.16392	.00	.64	
	>50	22	.4964	.12151	.00	.62	
	Total	100	.5334	.08942	.00	.64	

Table (4-5b) Brain AP sagtal , Brain AP Length , Brain Ap axial , Brain transvere axial table for variables distribution according to age

Descriptives							
		N	Mean	Std. Deviation	Minimum	Maximum	P -value
Brain AP sagtal	<10	6	143.5583	9.50841	131.86	159.21	.002
	11-20	28	158.4639	7.19019	142.05	170.60	
	21-30	19	154.8037	8.45380	135.30	171.90	
	31-40	13	156.0138	6.24504	146.68	168.47	
	41-50	12	158.5333	6.35491	149.52	174.72	
	>50	22	157.9482	8.52786	139.40	172.66	
	Total	100	156.4505	8.31206	131.86	174.72	
Brain AP Length	<10	6	88.1383	6.45736	79.35	96.80	.002
	11-20	28	102.3900	10.89059	57.25	116.89	
	21-30	19	100.3595	5.66489	86.41	109.04	
	31-40	13	99.6877	6.80607	88.89	113.34	
	41-50	12	104.2100	4.56259	97.42	111.89	
	>50	22	99.1532	5.47430	85.62	108.93	
	Total	100	100.3041	8.18333	57.25	116.89	
Brain Ap axial	<10	6	146.4633	10.72192	126.28	158.37	.000
	11-20	28	161.9343	8.27932	145.27	176.18	
	21-30	19	161.1495	7.98706	141.64	178.96	
	31-40	13	160.9762	4.49775	153.03	169.02	
	41-50	12	165.2367	5.83370	159.38	176.83	
	>50	22	165.9573	6.51053	146.65	176.08	
	Total	100	162.0137	8.42502	126.28	178.96	
Brain transvere axial	<10	6	115.2117	7.76681	103.19	122.21	.437
	11-20	28	120.3046	5.89661	106.61	133.86	
	21-30	19	120.7411	5.73579	103.70	130.86	
	31-40	13	118.5831	5.61607	109.02	129.07	
	41-50	12	120.7475	5.70425	111.09	132.44	
	>50	22	120.0245	6.63216	109.01	134.67	
	Total	100	119.8497	6.09177	103.19	134.67	

P value is considered significant at p = 0.005

Table (4-6) display table for variables distribution according to gender

Descriptives							
		N	Mean	Std. Deviation	Minimum	Maximum	P -value
Brain AP Length	Male	50	98.4952	9.41071	57.25	115.30	.026
	Female	50	102.1130	6.32938	84.18	116.89	
	Total	100	100.3041	8.18333	57.25	116.89	
CC length	Male	50	74.2446	7.88008	46.90	89.73	.034
	Female	50	77.2620	6.01837	58.05	93.74	
	Total	100	75.7533	7.13869	46.90	93.74	
Thickness genu Aa	Male	50	17.4778	2.11141	13.18	22.45	.756
	Female	50	17.6116	2.18718	12.95	21.77	
	Total	100	17.5447	2.13980	12.95	22.45	
Thickness body Bb	Male	50	6.8532	1.00520	4.89	9.69	.688
	Female	50	6.9410	1.16808	4.24	8.53	
	Total	100	6.8971	1.08507	4.24	9.69	
Thickness splenum cc	Male	50	16.1350	2.47159	4.78	22.09	.010
	Female	50	17.3944	2.29928	8.88	23.46	
	Total	100	16.7647	2.45778	4.78	23.46	
CCI	Male	50	.5334	.08674	.00	.62	.995
	Female	50	.5333	.09291	.00	.64	
	Total	100	.5334	.08942	.00	.64	
Brainb AP sagtal	Male	50	156.4128	8.40008	131.86	171.90	.964
	Female	50	156.4882	8.30821	135.30	174.72	
	Total	100	156.4505	8.31206	131.86	174.72	
Brain Ap oxial	Male	50	162.6688	9.77553	126.28	178.96	.440
	Female	50	161.3586	6.85375	141.64	176.83	
	Total	100	162.0137	8.42502	126.28	178.96	
Brain transvere oxial	Male	50	121.0614	6.27090	103.19	134.67	.046
	Female	50	118.6380	5.71455	103.70	131.46	
	Total	100	119.8497	6.09177	103.19	134.67	

Table (4.7) coefficients of variable

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.328	.072		4.585	.000
	Thickness genu Aa	.012	.004	.279	2.882	.005
a. Dependent Variable: Cci						

$$CCI = 0.328 + 0.012 \times 17.5$$

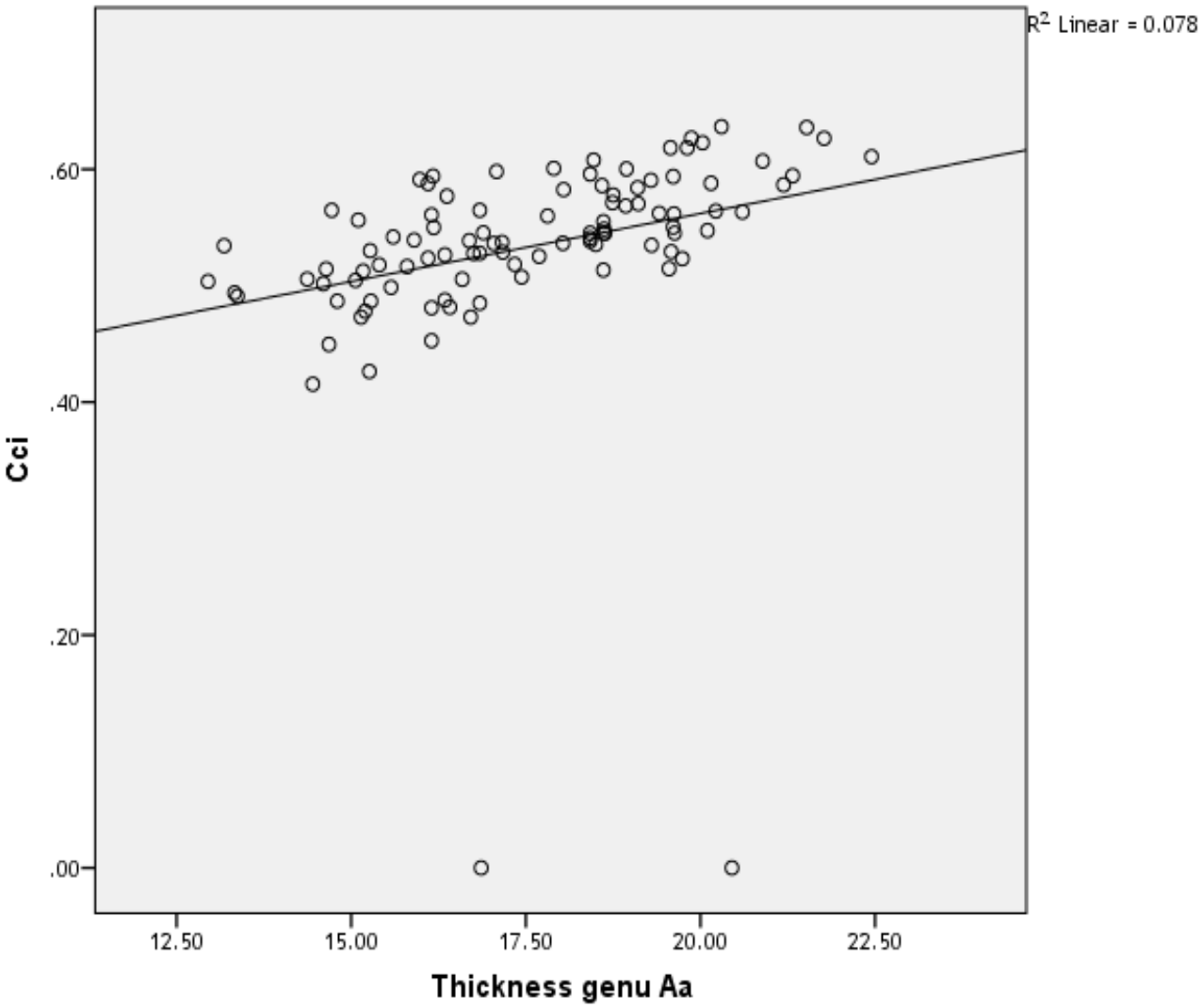
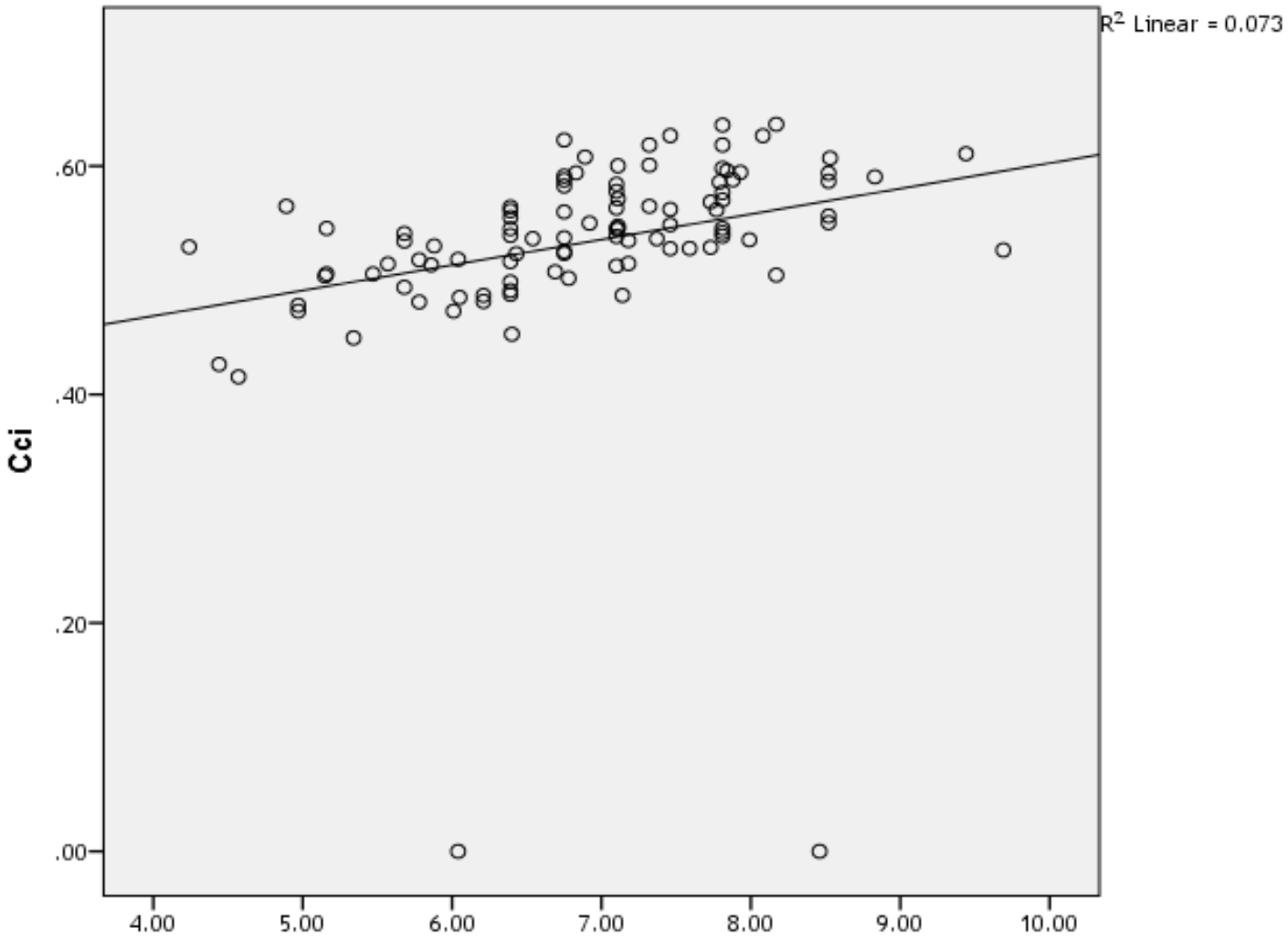


Fig (4-3) : shows the linear relation between thickness of Genu and CCI

Table (4.8) thickness body Bb

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.379	.056		6.783	.000
	Thickness body Bb	.022	.008	.271	2.784	.006
a. Dependent Variable: Cci						

CCI =0.379+0.022* Thickness body Bb



The relation between CCI and Thickness

Chapter five

5-1 . DISCUSSION

Table [2] presented the data obtained from Sudanese population who were examined by MRI sagital cuts for brain. The study results were presented for the measurements related to age classes .The relations between the corpus callosum (CC) parameters and Index with age was found to be significant at p0.005.

That means that the age has an impact on the (CCI).

Age -related changes in (CC) morphology are controversial. Although many studies have concluded that age- related callosal thinning is modest (Johnosn et al 1994).Some studies have reported that it is statistically significant. (Weis, et al , 1993) Most cross sectional MRI studies of the (CC) fail to show age- related shrinkage in adults from 3rd-7th decade.(Pfefferbaum , et al 1996) In contrast one study have shown senescent effects over 3rd-8th decades. (Doraiswamy , et al 1991) Another has found age effects in elderly subjects especially those exceeding 55 years. (Salat, et al 1997) Sullivan et al (Sullivan et al 2002) reported statistically significant thinning of genu, body and splenium with age on MRI study of mid sagittal brain sections, our results were similar to these previous results.

As a result, we observed that (CC) is being developed significantly from childhood to adult ages and in this growth, the gender does not make difference. We concluded that in studies subjected to (CC) with respect to pathological differences; it would be useful to consider the same age group records. Knowledge of (CC) morphology and the gender as well as age- related changes, thus is likely to be helpful in providing baseline data for the diagnosis of presence and progression of disease.

The corpus callosum is the major anatomic and functional inter hemispheric commissure in the human brain (Tejal ,et al , 2003).Corpus callosum dimensions, and sex-related differences have been of significance to

researchers, because they influence the performance of callosotomies in patients with intractable epilepsy.

Reports describing numerous conflicting studies have been published with respect to variations in the size of the corpus callosum relative to, gender and age (Mourgela ,et al , 2007) Corpus callosum, being the major structure connecting both the hemispheres, is likely to be affected by the physiologic as well as pathological changes occurring in the cortical and sub cortical regions of brain. Therefore different sub regions of the (CC) may be affected depending upon the region of the brain involved, as fiber systems connecting corresponding hemispheric regions pass through specific callosal sub regions. Therefore, alteration in (CC) morphology may give a clue towards diagnosis of specific disease processes. A knowledge of the normal (CC) morphology and the gender as well as age related changes, thus is likely to be helpful in providing baseline data for the diagnosis of presence of any pathological changes The goal of this work was to provide gender-specific reference data detailing the development of the corpus callosum based on MRI data from hundred healthy Sudanese subjects aged 34.64±20.61years.

MR imaging enables the study of cerebral structure and function. Several neuro-imaging studies have used the midsagittal area of the corpus callosum to show differences in morphology related to sex (Habib , etal , 1991), aging (Hussein , et al 1991), and pathologic states (Laissy, et al 1993). The corpus callosum has been shown to be altered in conditions such as schizophrenia (Suganthy , et al , 2003) even when visual assessment of the MR images reveals normal findings. Quantitative measures of the corpus callosum have been proposed as useful indicators of disease progression. The results of most of these MR imaging studies remain conflicting and controversial (Tejal , et all 2003)) The study showed that the females (CC) length is greater than males, as seen in table (1), adverse findings were noted by (Suganthy et al, 2003l) and (Elster et al,1993).

Several studies have found significant sex differences in the length, shape and area of the corpus callosum of males and females; with females having larger relative splenial width.[17-21] which is similar to our findings in Sudanese. Justification for our study results was that the sexual dimorphism in (CC) might be due to greater bi- hemispherical representation of cognitive functions in females. [Sullivan, et al , 2001]. (DeLacoste-Utamsing and Holloway, 1982) found the splenium to be larger in females. The previous studies results concerning differences in absolute measures have infrequently been replicated [19,20] Still the direction of non-significant absolute size differences in the (CC) is not consistent, with some studies showing larger measures in males [Witelsion, Demeter (1985,1988) others in females (Holloway, Deneberg , et al 1986,1991).The sexual dimorphism of the human corpus callosum (CC) is currently controversial, possibly because of difficulties in morphometric analysis.Clarke et al ,1989) The controversies may be due to differences in race of subjects under study or differences in the method of measurement. In the studies, there are groups stating that there are differences between male and female in respect to (CC) morphometry,Se Bellis et al , 2001) as well as the groups stating no difference.(Leonard , Takeda , et al 2003 ,2008) Ferrario et al have

reported that effects are meaningful considering the age increase, while no meaning in respect to genders,(Ferrario , et al 1996) .This was consistent with our findings. Comparing with other Asian population (Kosar , etal (2012); CCI for Sudanese is found to be greater. There are many causes which may affect (CC) morphology; such as, demiyelizan diseases, congenital anomalies, (Hayakawa , et al 1989) In such cases, for evaluation, besides the quantitative methods of area, length, width, we believe usage of a reliability proven index for Sudanese might be useful.

5-2 CONCLUSION

No significant difference in corpus callosum between both male and female gender measurements -in CCI . there is a little difference in the size of the corpus callosum with age -, it is clear that corpus callosum in the female larger than male with elder age. using MRI T1 weighted multi section sagital conventional give better accurate estimate of measurement

5-3 RECOMMENDATION

Further studies to find the difference in carpus callosum measurements with age -further studies on sick people . and people who are not sick . for more knowledge -use software technology instead of the equation. Case 100 divided by 50 female and 50 male.

It is useful to provide basic data for measurements of the carpus callosum even be compared in the event of a disease.

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APPENDICES

Appendix (1) Chart of data Collection as proposal to be filled

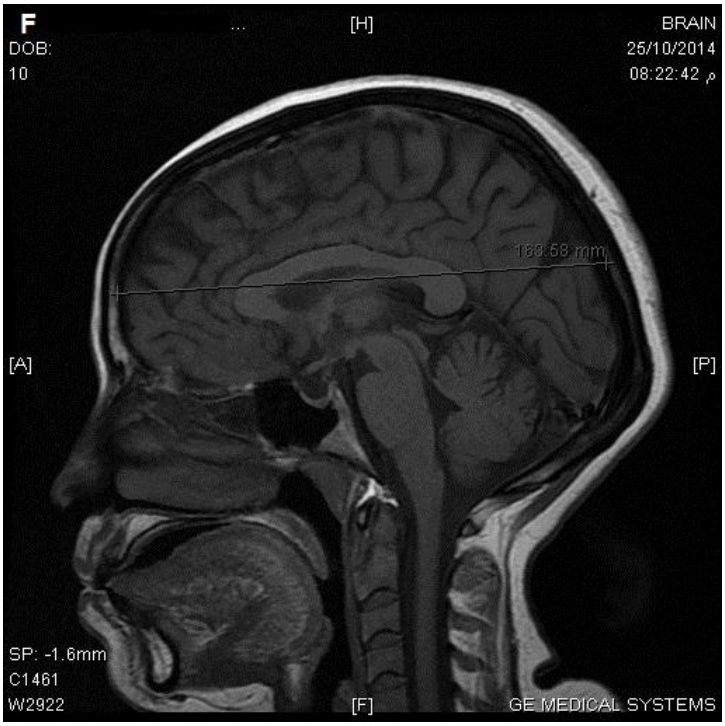
Female Sudanese populations /50											
م		age	Brain AP Length	Cc length	Thickness genu Aa	Thickness body Bb	Thickness splenum cc	Cci $\frac{Aa+bb+cc}{ab}$	Brainb AP sagtal	Brain Ap oxial	Brain transvere oxial

Female Sudanese populations /50											
م		age	Brain AP Length	Cc length	Thickness genu Aa	Thickness body Bb	Thickness splenum cc	Cci $\frac{Aa+bb+cc}{ab}$	Brainb AP sagtal	Brain Ap oxial	Brain transvere oxial

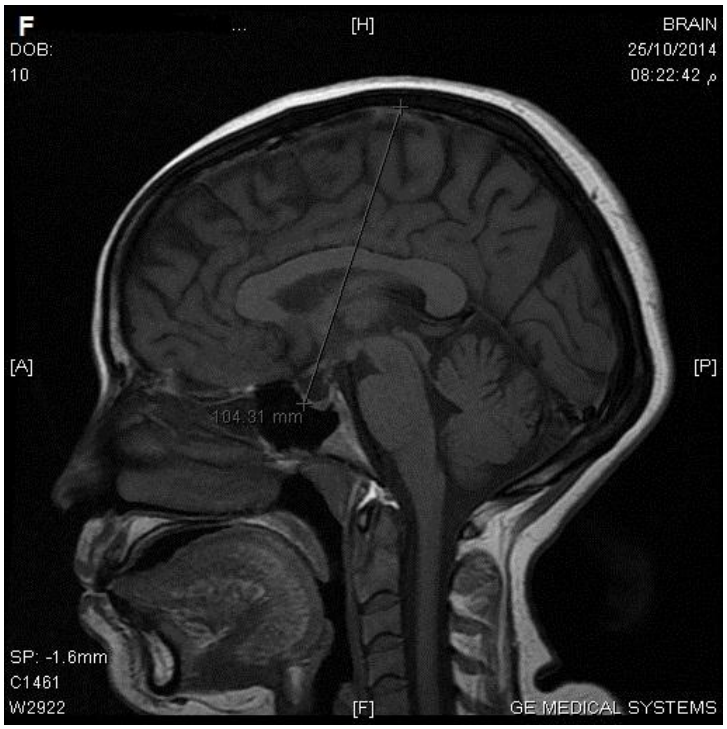
Male Sudanese populations /50											
م		age	Brain AP Length	Cc length	Thickness genu Aa	Thickness body Bb	Thickness splenum cc	Cci $\frac{Aa+bb+cc}{ab}$	Brainb AP sagtal	Brain Ap oxial	Brain transvere oxial

Male Sudanese populations /50											
م		age	Brain AP Length	Cc length	Thickness genu Aa	Thickness body Bb	Thickness splenum cc	Cci $\frac{Aa+bb+cc}{ab}$	Brainb AP sagtal	Brain Ap oxial	Brain transvere oxial

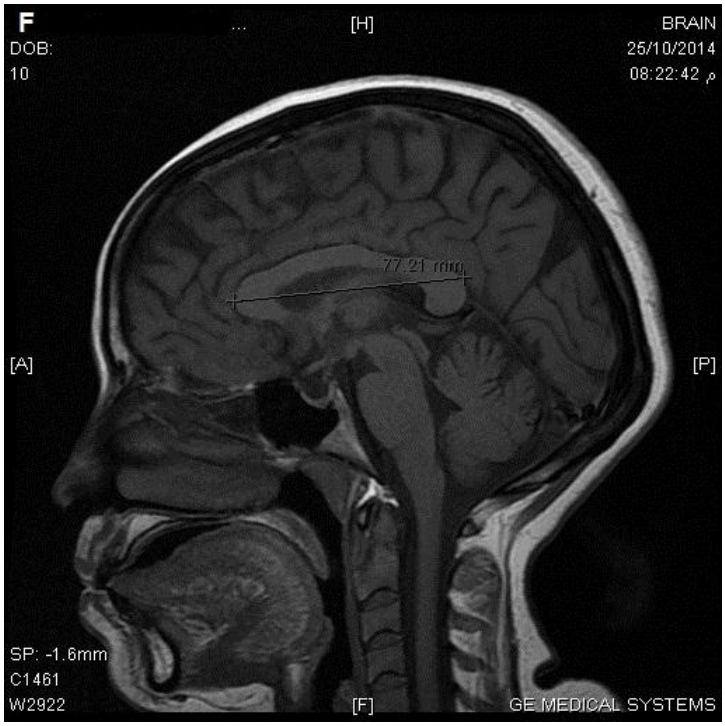
Appendix (2)
Image



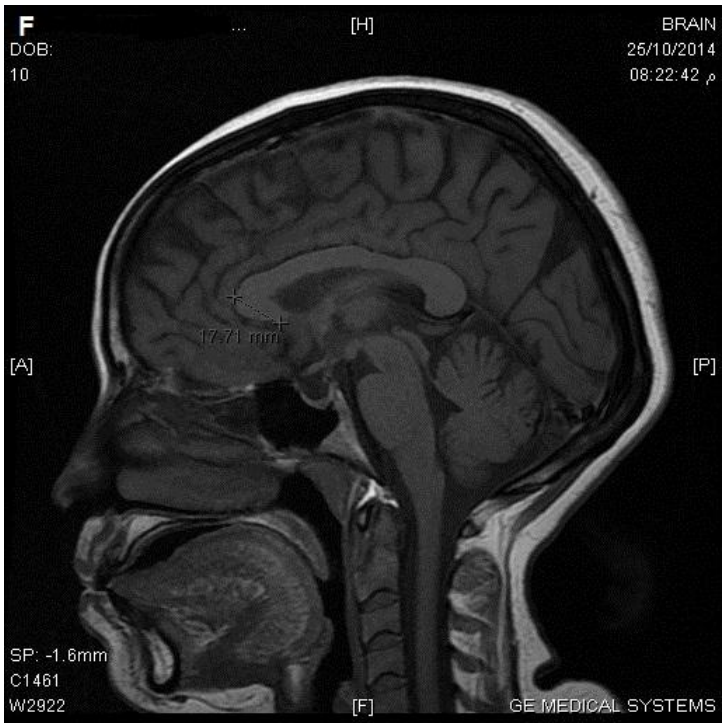
In figure ((1)) Female age 42 year old – segatal T1 of CC
Measure was taken in italics passing through the body



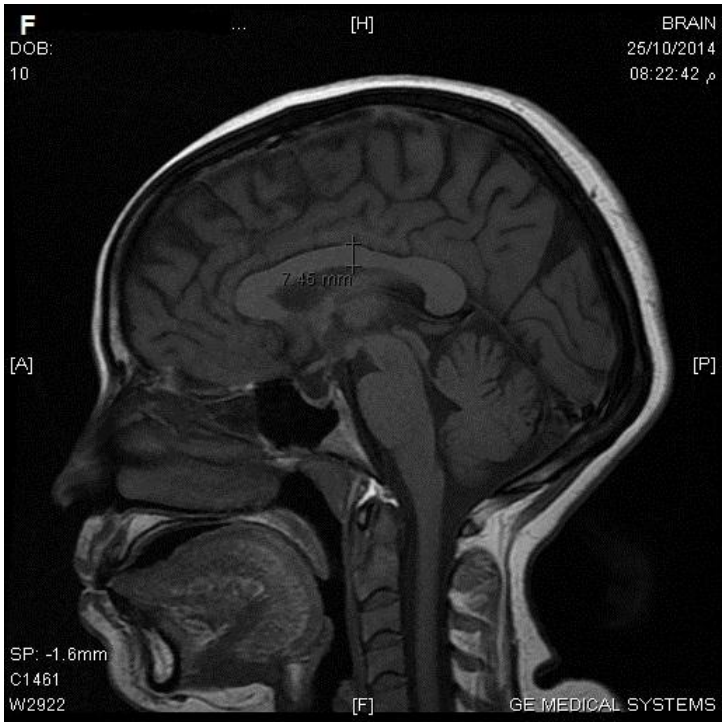
In figure ((2)) Female age 42 years old
Measurements was taken casual line going through Genu and splenium



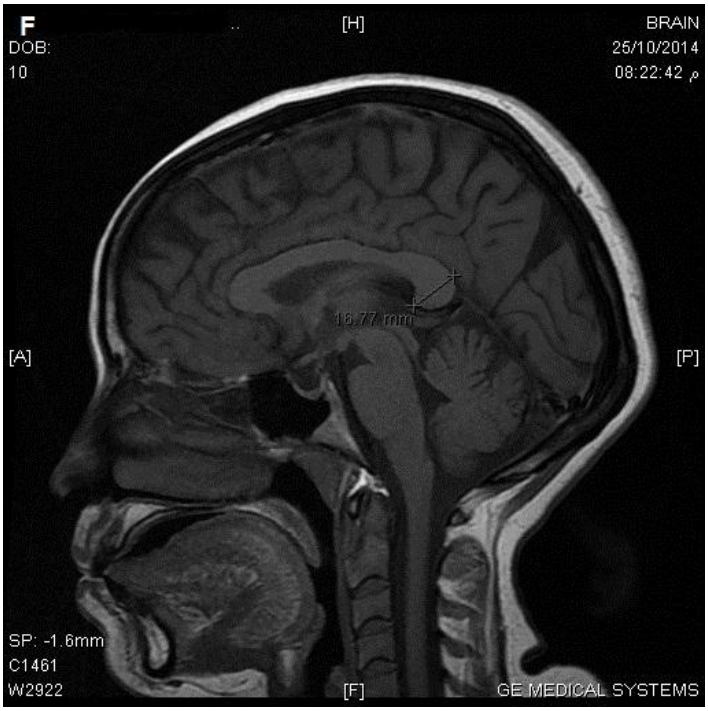
In figure ((3)) Female
The corpus callosum measure starting from Genu until splenium



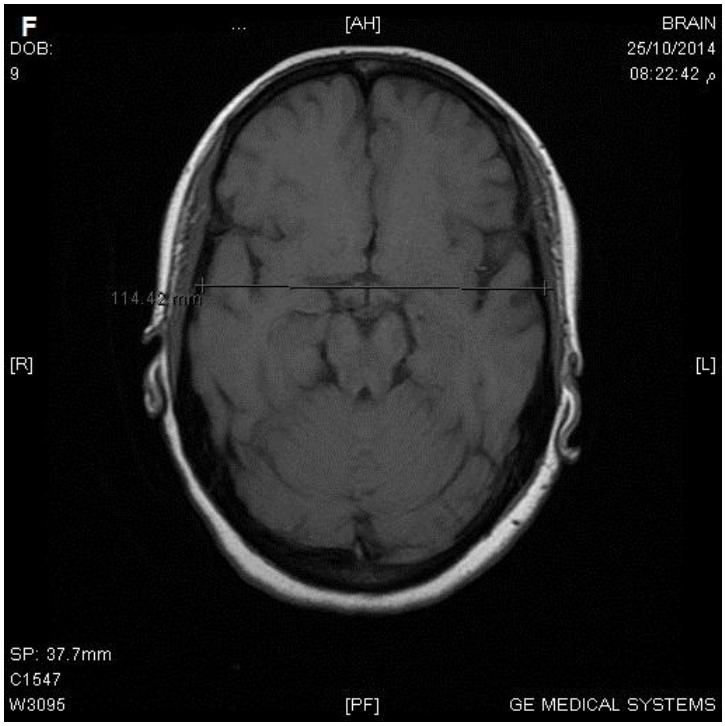
In figure ((4)) Female
Measurements was taken in italics began in Genu and ended with Rostrum



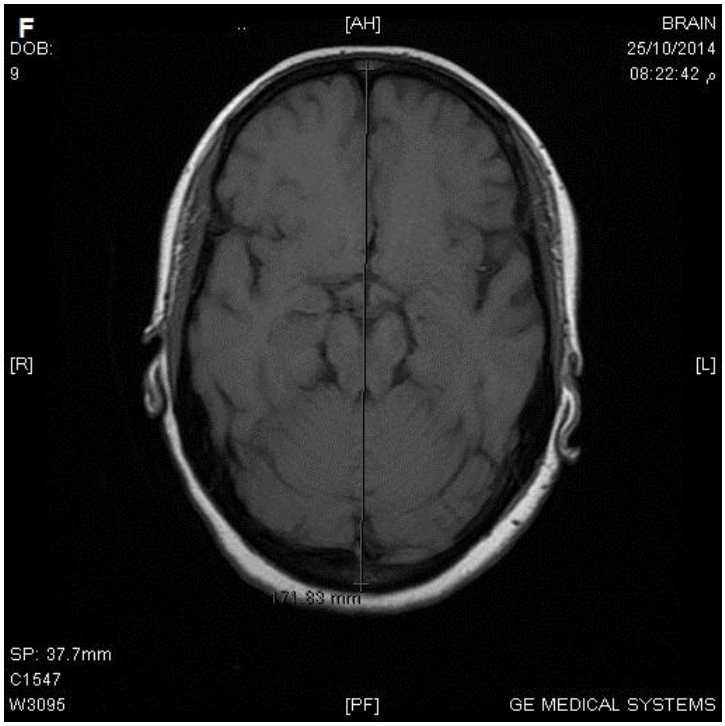
In figure ((5)) Female
The body was taken to measure vertical line



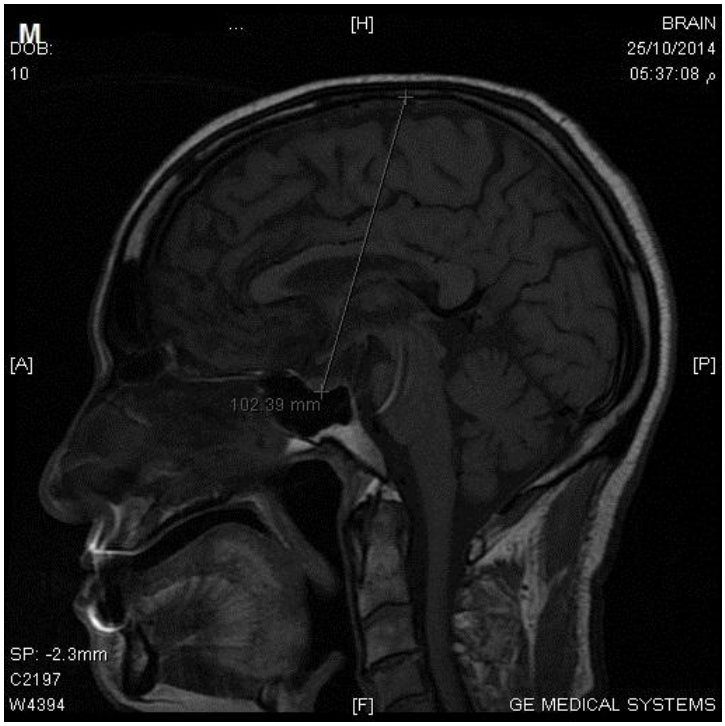
In figure ((6)) Female
Splenium measure was taken in italics



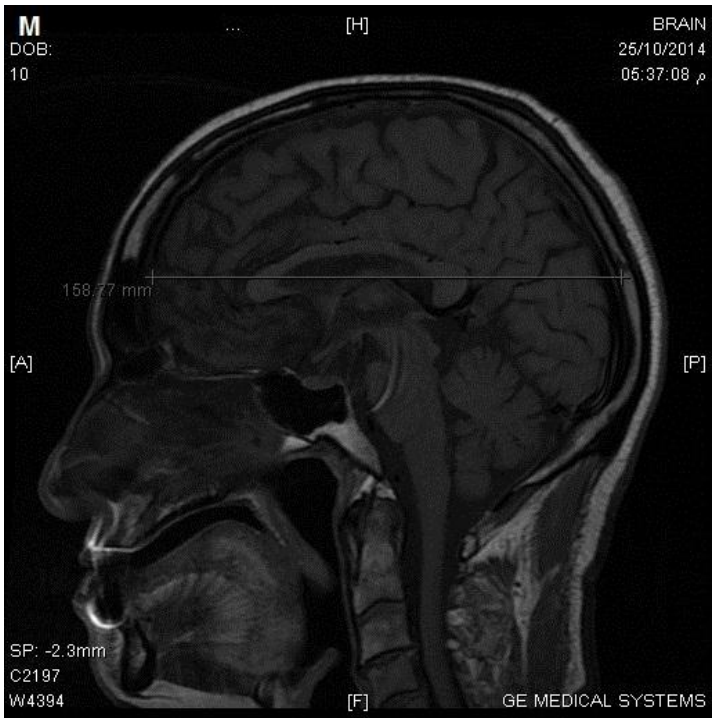
In figure ((7)) Female
It was taken to measure the Brain s casual line



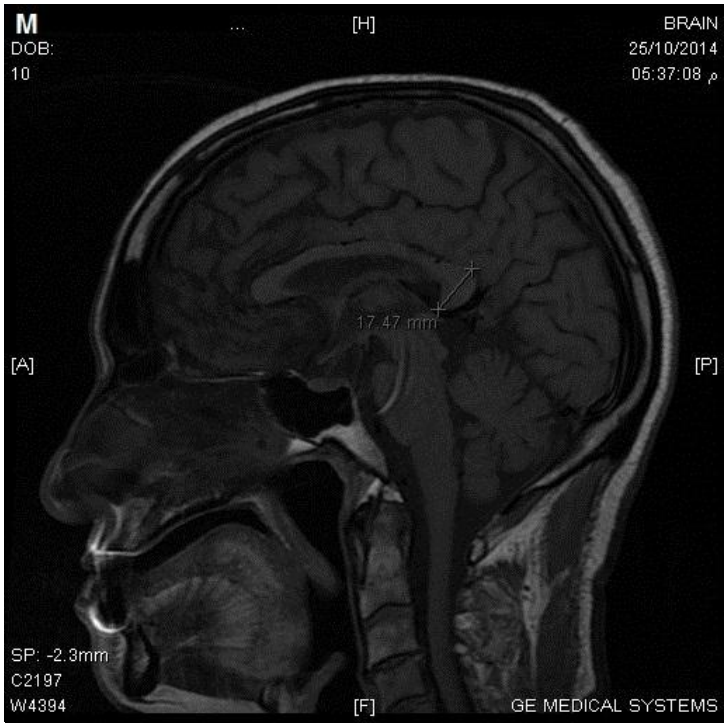
In figure ((8)) Female
It was taken to measure Brain longitudinal line



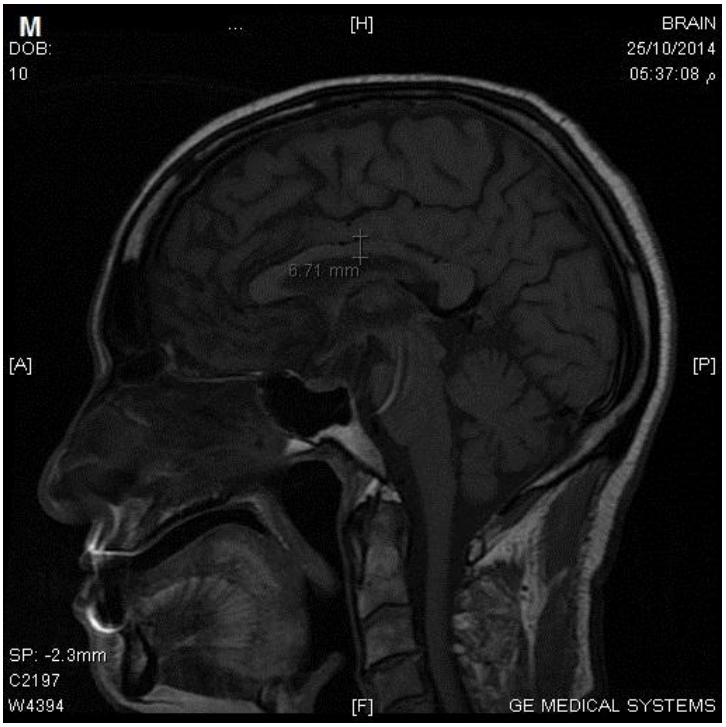
In figure ((1))Male – age 47 years old
Measure was taken in italics passing through the body



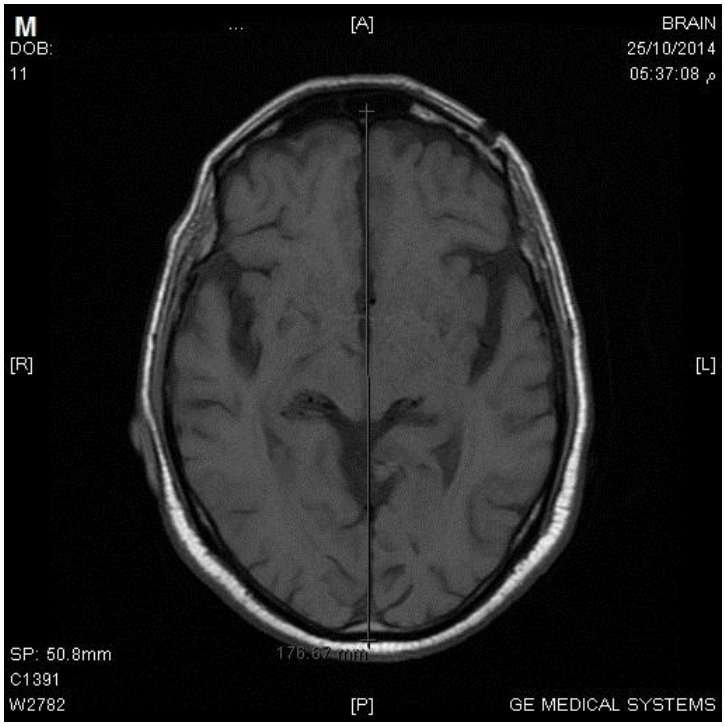
In figure ((2))Male
Measurements was taken casual line going through Genu and splenium



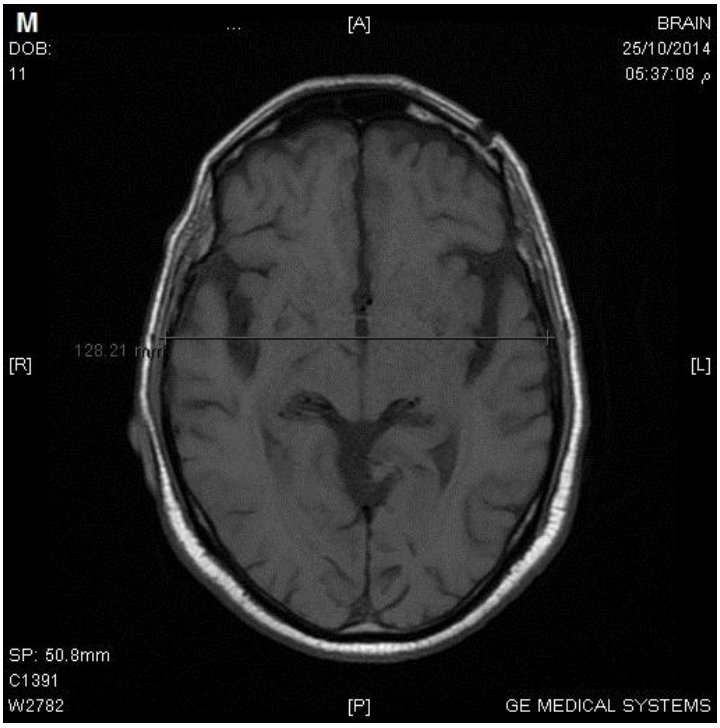
In figure ((3))Male
Measurements was taken in italics began in Genu and ended with Rostrum



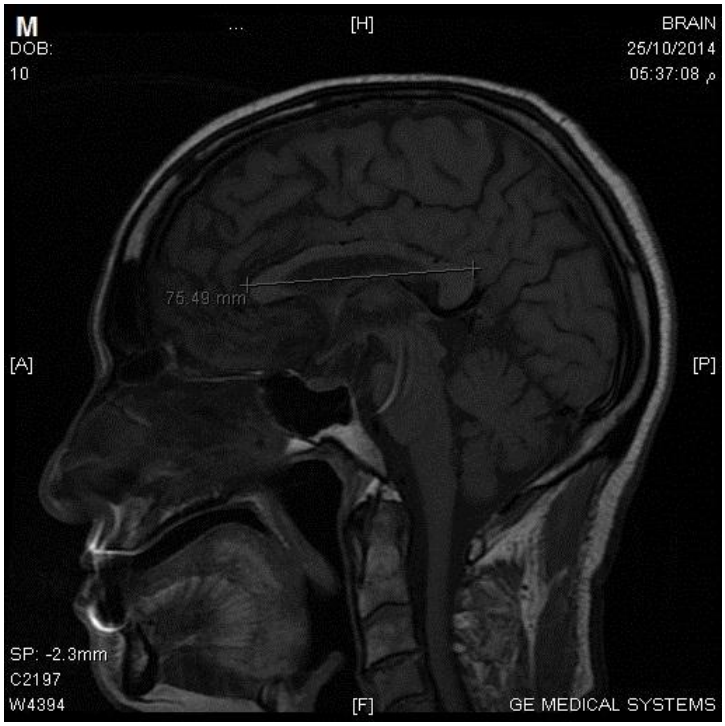
In figure ((4))Male
Splenium measure was taken in italics



In figure ((5)) Male
The body was taken to measure vertical line



In figure ((6)) Male
It was taken to measure Brain longitudinal line



In figure ((7)) Male
It was taken to measure the Brain s casual line

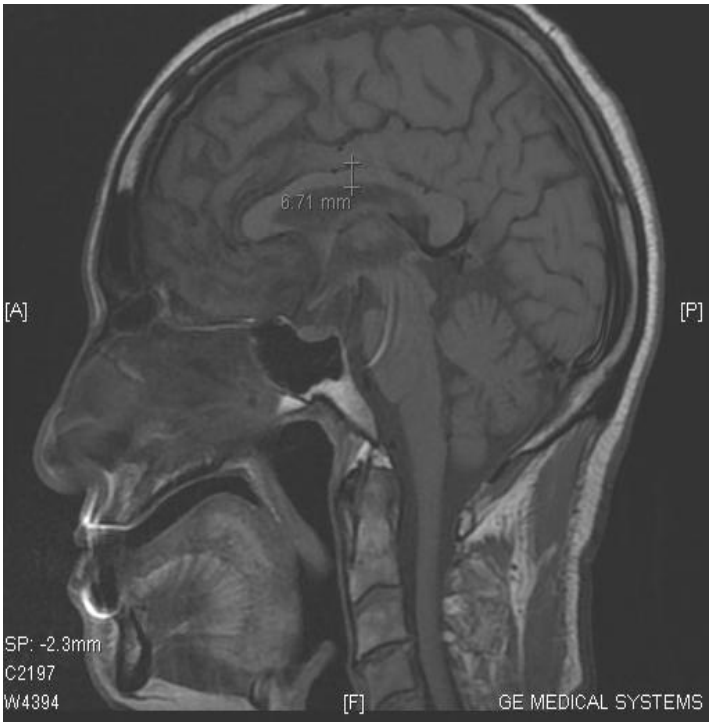


Figure (8) : The sagittal plane of T_1-weighted image of head magnetic resonance imaging (MRI). The corpus callosum

Magnetic resonance imaging in the user's machine samples

Magnetic resonance imaging in the user's machine samples.

م	age	Brain AP Length	Cc length	Thickness genu Aa	Thickness body Bb	Thickness splenum cc	Cci $\frac{Aa+bb+cc}{ab}$	Brainb AP sagtal	Brain Ap oxial	Brain transve oxial