Sudan University of Science & Technology
College of Graduate Studies

Characterization of Corpus Callosum using Magnetic Resonance Imaging for Sudanese Population

توصيف الجسم الثفني بالدماغ باستخدام التصوير بالرنين المغنطيسي لدى السودانيين

A thesis Submitted for the requirement of PhD degree in Diagnostic Radiological Technology

By: Amna Mohammed Ahmed Ibrahim

Supervised by:

Dr. Caroleen Edward Ayad
Associate Professor

Co-Supervisor:
Dr. Mohamed Elfadil Mohamed

Associate Professor

August 2017

Abstract

Morphometric of the corpus callosum (CC) are important to have normative values according to gender, age and race/ethnicity. The present study examined the correlation between age, gender, and CC morphometrical data, across ages <10> 60 years old to characterize normal developmental alternations in order to be a standard local reference for Sudanese. At issue the objectives are also to examine whether CC index continues to increase throughout life, whether there are regional differences in measurements of CC maturation, and whether these outlines are sexually demographic. As well this study concern to characterize the corpus collosum parts to splenium, trunk and genu using first order statisticand extract classification features from MR images. The CC on magnetic resonance midsagittal T1 weighted images was measured in 233 normal Sudanese subjects, (126 were males constituting 54.1% and 107 were females constituting 45.9%) admitted to Royal care international hospital, and scanned with MRI scanner of 1.5 Tesla (Toshiba) during the period extended from 2014 – 2017. Considering age and gender; Fronto occipital maximum brain length, Thickness of CC compartments at its maximum level for rostrum, genu, body/ trunk and splenium, CC greatest anteroposterior (AP) diameter, fronto-corpus callosum length, occipito-corpus callosum length and corpus callosum index (CCI) were measured as well the first order statistic (FOS) techniques included eight’s features which are mean, variance, coarseness, skewness, kurtosis, energy and entropy to find the gray level variation in MR images it complements the FOS features extracted from MR images with variation of gray level in pixels and estimate the size variated of the sub patterns. Data were analyzed using statistical package of social science (SPSS) program (Version.16), for texture analysis analyzing the image with

interactive data language (IDL) software to measure the grey level variation of images. Result showed that all dimensions of CC compartments in males were (rostrum =1.27mm, genu =11.33mm, trunk =5.91 and splenium =10.31mm) and for female were (rostrum =1.21mm, genu =11.83mm, trunk =6.56 and splenium =11.04 mm) and brain dimensions had significant relation with increasing age except for occipito-corpus callosum length where no significant relation was detected (p=0.126). The gender has an impact on the changes detected in the brain and CC compartments except for the rostrum, genu, callosal AP maximum diameter. Brain dimensions were significantly larger in males than in females at ($P \leq 0.05$). Another findings were found in the CC trunk, splenium maximum thickness and CCI, where females were greater than males with significant difference at P= 0.000, 0.011 and 0.031 respectively .The CCI increased with age and then decreased thereafter. There was also a positive linear relationship between the AP length of the CC and the fronto-corpus callosum length. Regression equation for predicting the length of the CC and morphometric index as local reference for normative data of CC during maturation in the Sudanese population in both genders at similar age classes have been established. The texture analysis results showed that the first order statistic and features give classification accuracy of corpus collosum parts for splenium 100.0%, trunk76.5% and the genu classification accuracy 97.0%. The overall classification accuracy of corpus collosum area 96.2%.These relationships are stored in a texture dictionary that can be later used to automatically annotate new MR images with the appropriate corpus collosum area names.

مستخلص البحث

يعتبر قياس البنية أو الشكل للجسم الثفني أمراً مهماً من أجل الحصول على قيم طبيعية حسب نوع الأشخاص وأعمارهم وأعراقهم . وقد قامت هذه الدراسة بإجراء فحوصات لإيجاد علاقة أو إرتباط بين العمر والنوع والبيانات الشكلية للجسم الثفني في الدماغ ، على عينة من الناس تفاوتت أعمارهم بين أقل من عشرة أعوام وأكبر من ستين عاماً ، من أجل توصيف التغييرات الطبيعية في النمو كي تستخدم كمرجع قياسي للسودانيين .وتضمنت أهداف الدراسة أيضاً قياس ومعرفة ما إذا كان مؤشر الجسم الثفني يستمر في الزيادة طول العمر ، وما إذا كانت هناك فروقات في تطور ونضوج المناطق المختلفة لهذا الجسم حسب القياسات ، وما إذا كانت هذه الفروقات مزدوجة الشكل حسب النوع .واهتمت الدراسة أيضاً بتوصيف أجزاء الجسم الثفني في مناطق الضمادة والجذع والركبة باستخدام مؤشرات التصنيف الإحصائي من الدرجة الأولى المستخلصة من صور الرنين المغناطيسي ثم قياس الجسم الثفني في المنطقة السهمية الوسطى من خلال صور الرنين المغناطيسي ، لعدد (233) شخص سوداني سليم (126 منهم ذكور يشكلون 54.1% ، و 107 إناث يشكلون 45.9%) تم تحويلهم إلى مستشفى رويال كير جرى فحصهم في أقسام التصوير بالرنين المغناطيسي ، وكانت فترة الدراسة من عام 2014م إلى 2017م . وبعد مراعاة عمر الشخص ونوعه تم قياس أقصى طول للدماغ من مقدمة الرأس إلى مؤخرته وقياس أجزاء الجسم الثفني في مستواه الأقصى للحصول على قياسات المنقار والركبة وجذع الجسم والضمادة وقياس القطر الأقصى للجسم الثفني من الجهة الأمامية خلفية وقياس طول الجسم الثفني الأمامي وطوله الخلفي ومؤشر الجسم الثفني .باستخدام تقنية الأمر الأولي الإحصائي التي اشتملت على ثماني متغيرات هي المتوسط والاختلاف والخشونة النسيج والطاقة والكيرتوسيس والإعتلاج من أجل الحصول على درجة الاختلاف في مستويات اللون الرمادي في صور الرنين المغناطيسي . تم تحليل البيانات باستخدام البرنامج الإحصائي للدراسات الإجتماعية (نسخة 16) في الحاسوب لتحليل النسيج من خلال الصور وبرمجيات لغة البيانات التفاعلية بقياس اختلاف درجات اللون الرمادي .أوضحت النتائج أن جميع أجزاء الجسم الثفني والدماغ لها علاقة ذات دلالة إحصائية بتقدم العمر ، ما عدا طول الجسم الثفني الخلفي ، حيث لا توجد علاقة . أوضحت النتائج أيضاً وجود أثر للتغيرات المكتشفة على الدماغ وأجزاء الجسم الثفني ما عدا مناطق المنقار والركبة والقطر الأقصى للجسم الثفني من الناحية الأمامية خلفية .وأظهرت الدراسات أيضاً أن دماغ الذكور أكبر من دماغ الإناث بدرجة اختلاف ($P \leq 0.05$) وكانت هناك نتائج اخرى في مناطق جذع الجسم الثفني والسمك الأقصى للضمادة ومؤشر الجسم الثفني حيث كانت في الإناث أكبر من الذكور بدرجات اختلاف تساوي $P = 0.000$ ، 0.011 ، 0.031على التوالي .كان مؤشر الجسم الثفني يزيد مع العمر ثم ينقص بعد ذلك . كانت هناك علاقة خطية بين الطول من الجهة الأمامية خلفية للجسم الثفني والطول الأمامي له . تم إيجاد وإبتكار معادلة إرتداد للتنبؤ بطول الجسم الثفني ومؤشر قياس البنية لتكون مرجعاً محلياً يحدد البيانات الخاصة بالجسم الثفني السليم أثناء نمو ونضوج السكان السودانيين من كلا الجنسين ، في نفس الفئة العمرية . أظهرت نتائج تحليل النسيج أن الإحصاءات من الدرجة الأولى أعطت دقة عالية

لتصنيف أجزاء الجسم الثقني ، بدرجات تصنيف هي 100% بالنسبة للضمادة و 76.5% للجذع و97% للركبة .وكانت النسبة الكلية للدقة في تصنيف منطقة الجسم الثقني هي 96.2% . تم تخزين هذه العلاقات في قاموس للنسيج بحيث يتم الاستفادة منها لاحقاً واستنتاج أفلام جديدة بمسميات نموذجية للجسم الثقني .

Dedication

To soul of my father, To my mother,,,,

This thesis would be incomplete without a mention of the support given me by my husband Atif Eltyeb who kept my spirits up. Without his lifting me up, I doubt it should ever have been completed.

I dedicate my thesis to my, sisters, brothers and friends who have supported me all the way since the beginning of my studies as well as to everyone whom gave me a bit of wise advice.

Acknowledgment

First of all, I Thank Allah the almighty for helping me to complete this project.

I would like to specify my acknowledgment to my supervisor Assoc. Prof. Dr. CAROLIN EDWARD and my Co-supervisor Assoc. Prof. Dr. Mohamed Elfadil Mohamed who are made a finger print in whole of my life not only the academic one, and for his encouragement, guidance and supports from the initial to the final level enable me to develop and understanding of the subject.

I am sincerely thanks with whom the study would not have been feasible, Sudan University of Sciences and Technology, Modern Medical Center, Royal care international hospital

List of Contents

List of Figures

List of tables

List of abbreviations

3D	: Three Dimensional
ACC	: Agenesis of the Corpus Callosum
ACOM	: Anterior communicating artery
C I	: Classification Image
CC	: Corpus Callosum
CCI	: Corpus Callosum Index
CCMAPD	: Corpus callosum maximum antero posterior diameter
CNS	: Central Nervous System
CT	: Computed Tomography
dMRI	: Diffusion Magnetic Resonance Imaging
DTI	: Diffusion tensor imaging
FOML	: Fronto occipital maximum length
FOS	: First Order Statistics
IDL	: Interactive Data Language
Mm	: Mille meter
MR	: Magnetic Resonance
MRI	: Magnetic Resonance Imaging
SPSS	: Statistical Package of Social Science
STDV	: Stander Deviation
TE	: Time to Echo
TR	: Time to Repeat

Chapter One

1.1 Introduction

Neuroimaging of the corpus callosum (CC) has attracted the researchers in both medical and neuroscience awareness in the past few decades (Timothy et al.2012). Callosal changes due to brain atrophy were characterized in many diseases (DiPaola et al. 2010; Hasan et al. 2012) as well the abnormalities in callosal morphology have also been reported in neuropsychiatric disorders (Bearden et al .2011), developmental disorders (Paul et al.2011), also changes are found during normal human development and aging (Luders et al.2010), with callosal morphology reflecting gender differences (Gurd et al.2012). Regarding differences in the size of humans 'organs including CC according to race/ ethnicity; CC dimensions, morphology and sex-related differences have been of interest to investigators (Mourgela et al. 2007). Most of the studies on the morphometrery of CC were carried out in Western countries on the Caucasian population (Peterson et al.2001; Luders et al. 2003) and a few studies were performed in the East Asian population (Takeda et al. 2003; Okamoto et al. 1990). Minimal variability in the dimensions and relative dimensions of the CC in Greek people was reported (Mourgela et al. 2007). Takada in 2003 did not observe any difference in the regional size of CC between genders in Japanese subjects (Takeda et al.2003). On the other hand; another study found a well established difference in size, shape and position of the CC between genders (Bermudez et al. 2001). Magnetic resonance imaging (MRI) provides the most resolute images of the CC compared with the other imaging modalities (Reinarz et al.1988). MRI is regarded as the best method to obtain cross-sectional area and shape information of corpus callosum. In addition, MRI is fast and safe, without any radiation exposure to the subject such as with X-ray, CT. Since manual tracing of corpus callosum in MR images is time consuming, operator dependent (Gupta et al. (2011). The corpus callosum is a structure of the mammalian brain in the longitudinal fissure that connects the left and right cerebral hemispheres. It is the largest white matter structure in the brain, consisting of 200-250 million contra lateral axonal projections. It is a wide, flat bundle of axons beneath the cortex. Much of the inter-hemispheric communication in the brain is conducted across the corpus callosum. It is 10 cm long and consists of the rostrum, genu, trunk and splenium. Rostrum is the narrowest part; Genu is the most anteriorly projecting part and lies about 4cm from frontal pole. Trunk (Body) is the main part of corpus callosum. Splenium is the thickened posterior end of corpus callosum and lies about 6 cm from occipital pole. (Standring et al. 2005).To the best of our knowledge; no study has been obtained for Sudanese to characterize the norms, as clearly; there is a lack of comprehensive reference data with respect to callosal maturation. All data were interrelated to American, European, or Asian populations.

Texture analysis can be defined as the relationship between the pixels; therefore it can pick up the microscopic structures and hence it is superior to visual perception which is solely subjective. Texture can be calculate using a window of appropriate size that depict the underlined textures using features vector that correlated with the classes of interest for successful classification and segmentation of the underline textures through a suitable classifier (e.g. k-means, linear discriminate analysis, neural net work etc…).

Texture is an important characteristic for the analysis of many types of images. It can be seen in all images from multi spectral scanner images obtained from aircraft or satellite platforms (which the remote sensing community analyzes) to microscopic images of cell cultures or tissue samples (which the biomedical community analyzes).

Despite its importance and ubiquity in image data, a formal approach or precise definition of texture does not exist. (Haralick et al, 1979). Image texture, defined as a function of the spatial variation in pixel intensities (gray values), is useful in a variety of applications and has been a subject of intense study by many researchers. One immediate application of image texture is the recognition of image regions using texture properties. Texture is the most important visual cue in identifying these types of homogeneous regions. This is called texture classification. (Haralick et al, 1979). Image analysis techniques have played an important role in several medical applications. In general, the applications involve the automatic extraction of features from the image which is then used for a variety of classification tasks, such as distinguishing normal tissue from abnormal tissue. Depending upon the particular classification task, the extracted features capture morphological properties, color properties, or certain textural properties of the image.(Clausi et al., 2002).Texture is a combination of repeated patterns with a regular frequency. In visual interpretation texture has several types, for example, smooth, fine, coarse etc., which are often used in the classification of forest types. Texture analysis is defined as the classification or segmentation of textural features with respect to the shape of a small element, density and direction of regularity. In the case of digital image, it is difficult to 24 treat the texture mathematically because texture cannot be standardized quantitatively and the data volume is so huge. (Clausi et. al., 2002).Approaches to texture analysis are usually categorized into: Structural, statistical, model-based and, transform (Clausi et. al., 2002).

Texturally corpus callosum tissues in MRI can be identified using several types of textural measures. Texture analysis is a branch of image processing, which attempts to convey "texture" information from digital images, such as magnetic resonance images (MRI). The classification of magnetic resonance image data, more specifically the classification of MR image data according to the nature of the corpus callosum (Clausi et. al., 2002).

1.3 Problem of the study:

Corpus callosum is vital part of the human brain because it enhances and maintains communication between brain hemispheres. It is likely to be affected by the physiologic, as well as pathological changes occurred in the regions of brain. Also corpus callosum dimensions and texture might be change in respect to age which generally might insinuate or simulate pathology. Therefore Study of normal measurements of corpus callosum is helpful in providing baseline data for recognizing and diagnosing the presence and progression of diseases as well as to differentiate between degenerative changes and pathological changes. Texture analysis may be an important issue for characterizing of corpuscallosum, no study was obtained using both methods standard and texture analysis.

1.4 Objectives of the Study:

1.4.1 General objective:

The main objective of this thesis is to characterize corpus callosum in normal Sudanese population using magnetic resonance imaging (MRI).

1.4.2 Specific objectives:

- To measure the length and width of corpuscallosum parts (rostrum, spllinuom, body and ginu).
- To detect the changes in signal and texture in corpuscallosum (parts) in MRI in respect to age.

- To find the association between age, size and signal in corpuscallosum.
- To find an index of corpuscallosum measurements and texture identity versus age groups.
- To classify the corpuscallosum parts and to find within and between groups difference (in the same age groups and different age groups)

1.5. Significance of the study

This study provided a Sudanese index (dimension) for corpus callosum and the associated parts in the normal people and the changes in the measurement that attributed to ageing. As well as the textural identity for the corpus callosum as normal structures which will facilitate the identification of the pathological condition, which might be subtle in the normal visual perception evaluation.

1.6 Overview of the study:

The skeleton of thesis is built upon five chapters. Chapter one is consist of introduction, problem of the study, general, specific objectives and significant of the study. Chapter two concerns with Literature review. Chapter three is about the methodology which includes material and method, chapter four about the result presentation, chapter five about the discussion, conclusion, recommendation and limitations including the references and appendixes.

Chapter Two

Anatomy , Physiology and Pathology

2.1 Anatomy of the brain

Our limited knowledge about the human brain can be attributed to its complex nature. Basically, the brain is divided into two halves also known as hemispheres, the right brain and the left brain. Each of these hemispheres of the brain is assigned for particular tasks related to various human body functions. The right brain characteristics differ from the left brain characteristics to a significant extent. Yet another interesting fact on the human brain is that the right brain is concerned with the left side of the body, while the left brain is with the right side of our body so there has to be some link between these two hemispheres of the brain, and corpus callosum acts as this link which facilitates communication between two (Gupta et al. 2011). The brain consist of three main parts the cerebrum, the cerebellum, and the brain stem. The cerebrum consists of two cerebral hemispheres connected by a bundle of nerve fibers, the corpus callosum. The largest and most visible part of the brain, the cerebrum, appears as folded ridges and grooves, called convolutions. The following terms are used to describe the convolutions a gyrus is an elevated ridge, a sulcus is a shallow groove, and a fissure is a deep groove. The deeper fissures divided the cerebrum into five lobes (Figure 2.1) most lobes are named after bordering skull bones: the frontal lobe, the parietal lobe, the temporal lobe, the occipital lobe, and the insula. All but the insula are visible from the outside surface of the brain. The cerebral cortex is a thin outer layer of gray matter. The cerebral white matter underlies the cerebral cortex. It contains mostly myelinated axons that connect cerebral hemispheres association fibers, connect gyri within hemispheres (commissural fibers), or connect the cerebrum to the spinal cord (projection fibers). The corpus callosum is a major assemblage of association fibers that forms a nerve tract that connects the two cerebral hemispheres. (M.R.E Dean, 1990). Basal ganglia are several pockets of gray matter located deep inside the cerebral white matter. The major regions in the basal ganglia the caudate nuclei, the putamen, and the globus pallidus-are involved in relaying and modifying nerve impulses passing from the cerebral cortex to the spinal cord. The brainstem connects the diencephalon to the spinal cord. The brainstem resembles the spinal cord in that both consist of white matter fiber tracts surrounding a core of gray matter. The brainstem consists of the following four regions, all of which provide connections between various parts of the brain and between the brain and the spinal cord structures of the brainstem are Midbrain, uppermost part of the brainstem Pons, bulging region in the middle of the brainstem, medulla oblongata, reticular formation, within the white matter of the various regions of the brainstem and certain regions of the spinal cord, diencephalon, and cerebellum. Cerebellum is located dorsal to the pons and medulla and occupies the space between the brain stem and the occipital lobes of the cerebral cortex. It is connected to the brainstem by three peduncles (Vishram, 2004)

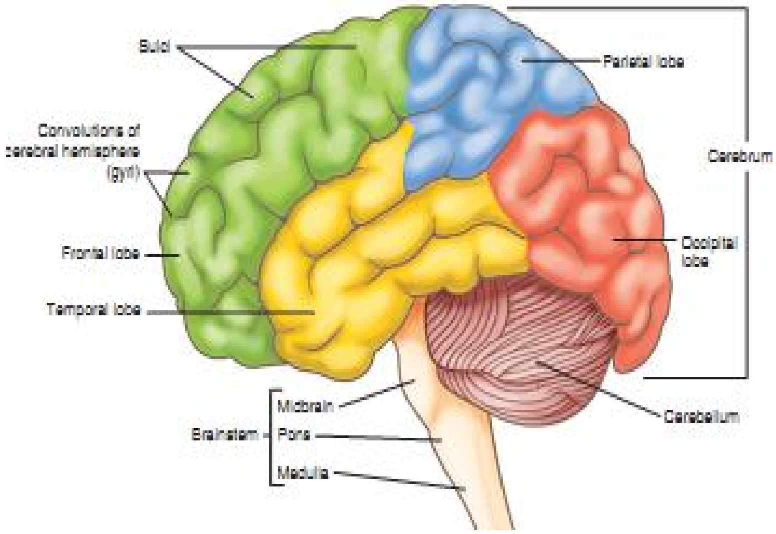


Figure 2.1 Showin sagittal sectionfor lobes of the brain

www.braintumoursurgery.co.uk/brain-anatomy/

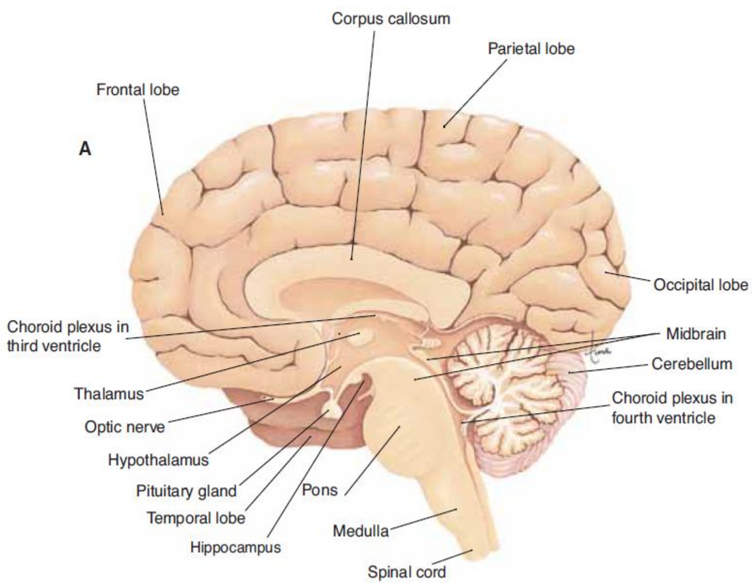


Figure 2.2 Showing Sagittal section for brain anatomy

www.sigrid.knemeyer.com/portfolio/mid-section-of-the-brain/

2.1.1 Blood supply of brain:

2.1.1.1Major blood vessels:

Normal function of the brain's control centers is dependent upon adequate supply of oxygen and nutrients through a dense network of blood vessels. Blood is supplied to the brain, face, and scalp via two major sets of vessels: the right and left common carotid arteries and the right and left vertebral arteries. The common carotid arteries have two divisions. The external carotid arteries supply the face and scalp with blood. The internal carotid arteries supply blood to the anterior three-fifths of cerebrum, except for parts of the temporal and occipital lobes. The vertebrobasilar arteries supply the posterior two-fifths of the cerebrum, part of the cerebellum, and the brainstem (Vishram, 2004). The brain is supplied with blood from four arteries: the two Internal Carotid arteries and the two Vertebral arteries. Upon reaching the forebrain, the Internal Carotid gives of the Anterior and Middle cerebral arteries. The two Vertebral arteries reach the ventral surface of the brainstem and give off the first pair of Cerebellar arteries before coming together to form the Basilar artery. The Basilar artery, in turn, gives rise to two additional pairs of Cerebellar arteries and the Posterior Cerebral artery (Keith, 2014).

2.1.1.2 Circle of Willis:

The circle of Willis encircles the stalk of the pituitary gland and provides important communications between the blood supply of the forebrain and hindbrain (ie, between the internal carotid and vertebro-basilar systems following obliteration of primitive embryonic connections). Although a complete circle of Willis is present in some individuals, it is rarely seen radio graphically in its entirety; anatomical variations are very common and a well-developed communication between each of its parts is identified in less than half of the population. The circle of Willis begins to form when the right and left internal carotid artery enters the cranial cavity and each one divides into two main branches: the anterior cerebral artery and middle cerebral artery . The anterior cerebral arteries are then united and blood can cross flow by the anterior communicating artery. The supply most midline portions of the frontal lobes and superior medial parietal lobes. The supply most of the lateral surface of the hemisphere, except the superior portion of the parietal lobe via anterior cerebral arteries and the inferior portion of the temporal lobe and occipital lobe. The anterior communicating artery, ACOM, and MCAs form the anterior half, or better known as the anterior circulation of the circle of Willis. Posteriorly, the basilar artery , formed by the left and right vertebral arteries, branches into a left and right posterior cerebral artery, forming the posterior circulation. The posterior cerebral artery mostly supply blood to the occipital lobe and inferior portion of the temporal lobe. At the base of the brain, the carotid and vertebrobasilar arteries form a circle of communicating arteries known as the Circle of Willis. From this circle, other arteries-the anterior cerebral artery, the middle cerebral artery, the posterior cerebral artery -arise and travel to all parts of the brain. Posterior Inferior Cerebellar Arteries, which branch from the vertebral arteries (Vishram, 2004). The cerebral vasculature comprises the arterial and venous systems. The brain is supplied by two pairs of arteries: internal carotid artery anteriorly and vertebral artery posteriorly. The anterior and posterior circulations are connected by the circle of Willis, from which originate three paired branches: anterior cerebral, middle cerebral, and posterior cerebral arteries. The venous system contains dural sinuses, and cerebral superficial and deep veins (Keith L.Moors,2014).

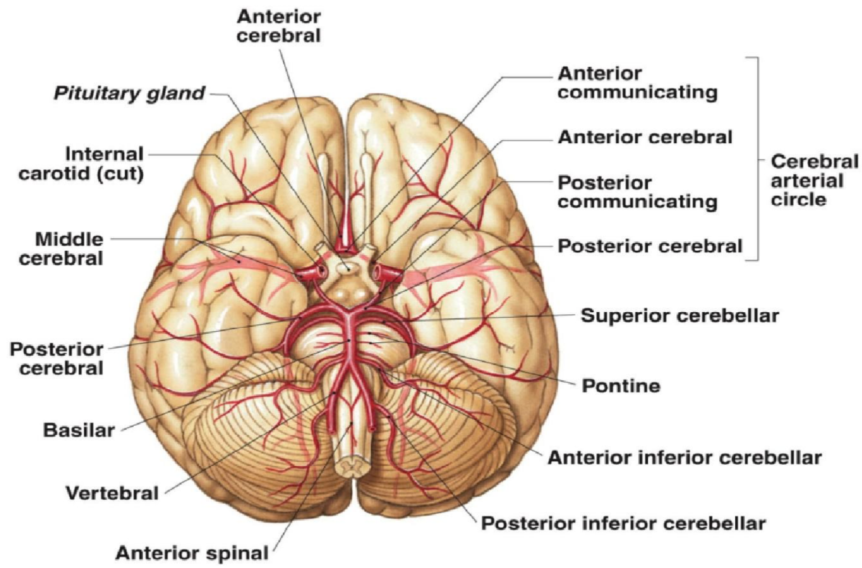


Figure 2.3 Showing Blood supply of the brain

www.csuchico.edu/~pmccaffrey//syllabi/cmsd%20320/362unit11.html

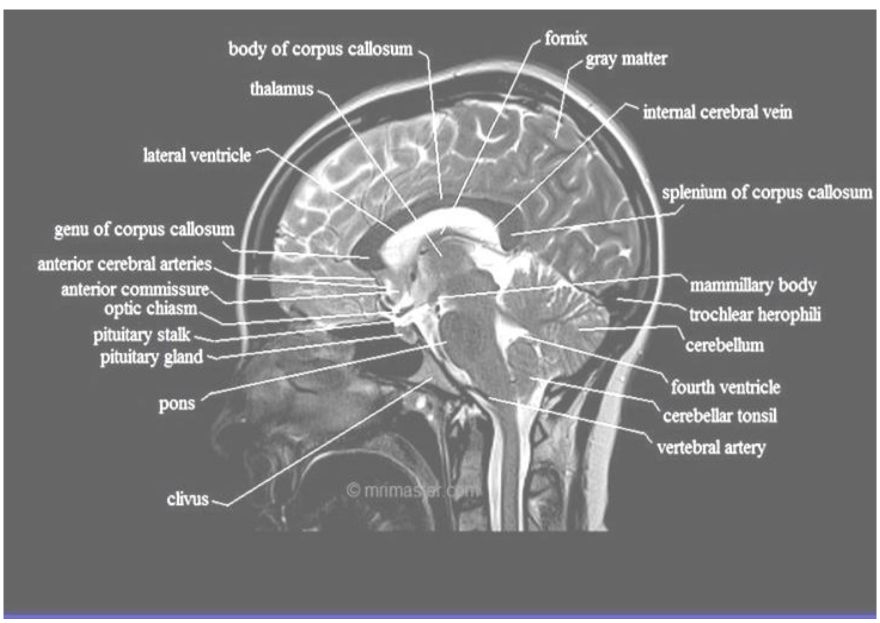


Figure 2.4 Showing MRI sagittal image T1 for crosectional anatomy of the brain

https://www.pinterest.com/evanmariah/cross-sectional-anatomymrct/

2.2 .Anatomy of corpus callosum:

Corpus callosum is a wide, flat bundle of nerve fibers located at the longitudinal fissure beneath the cortex. The term 'corpus callosum' means tough body in Latin. With approximately 200-250 million contra lateral axonal projections, corpus callosum is the largest among the various white matter structures in the central nervous system. The anterior portion of this structure is referred to as the 'genu', while the posterior portion is referred to as 'splenium'. In between the anterior and posterior portions of corpus callosum lies the body of the structure which is referred to as the 'truncus'. While the functions of the right hemisphere differ from that of the left hemisphere, there has to be some connection between the two halves of the brain in order to facilitate proper functioning of the nervous system as a whole. This is where the corpus callosum comes into the picture, as it facilitates this connection by acting as a bridge between the two hemispheres, and transmitting information from one hemisphere to the other. CC was thought to serve no other purpose than preventing the two hemispheres from collapsing on one another (Bogen, 1979) . Since then, the structure and function of the CC have remained topics of continuous investigation (Zaidel and Iacoboni 2003). Most anatomical studies of humans have relied on structural magnetic resonance imaging (MRI) morphometry of mid sagittal cross-section views of the CC. In contrast, a few recent studies have used diffusion tensor imaging (DTI) methods to re-evaluate callosal topography (Wahl et al. 2007). There are disputed claims about the difference in the size of the human corpus callosum in men and women and the relationship of any such differences to gender differences in human behaviour and cognition. A Philadelphia anatomist (Bean, 1906).suggested in 1906 that the "exceptional size of the corpus callosum may mean exceptional intellectual activity" and claimed differences in size between males and females and between races, although these were refuted by the director of his own laboratory in 1909(Mall ,1909) .Of much more substantial popular impact was a 1982 Science article claiming to be the first report of a reliable sex difference in human brain morphology, and arguing for relevance to cognitive gender differences. The corpus callosum is unique to placental mammals in the brain structure that connects the right and left hemispheres. It consists of approximately 200 million neural fibers and is responsible for interhemispheric transfer of information and higher-order cognition. The mostparsimonious explanation for callosal evolution is that it arose to facilitate long-distance integration within large brains. Callosal fibers are first found in human embryos at 10–11 weeks of gestation, and by 12–13 weeks a rudimentary callosal plate can be seen. The corpus callosum first enlarges caudally then develops rostrally. Myelination occurs relatively slowly over the lifespan, with the process completing in puberty. Myelination progresses caudally to rostrally, much as the corpus callosum develops, from the splenium to the genu and rostrum It begins to develop around the 12thweek of gestation and matures through a complex process of neuronal migration, development, and eventual neuronal pruning. By week 20, the corpus callosum can be seen on a sonogram or fetal MRI. Although the corpus callosum may be considered fully developed by around age 4, as with most neural structures, it likely continues to change over the lifespan. There are two types of fibers in the corpus callosum. Large diameter fibers mediate sensory-motor coordination whereas small diameter fibers connect association areas. The small diameter fibers are more numerous and individual differences in callosal size have been shown to be are flections of the small diameter type. It is these small diameter fibers that are thought to be important in maintaining the balance between excitation and inhibition in the cerebral hemispheres (Vishram, 2004).

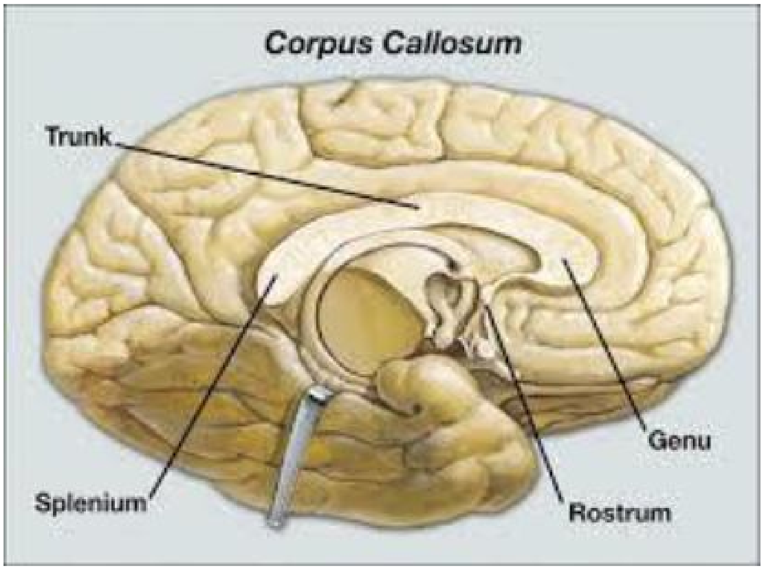


Figure 2.5 Show parts of corpus callosum (Rostrum, Genu, Trunk and Splenium)

www.studyblue.com/notes/note/n/25a-gross-brain-i/deck/13404661

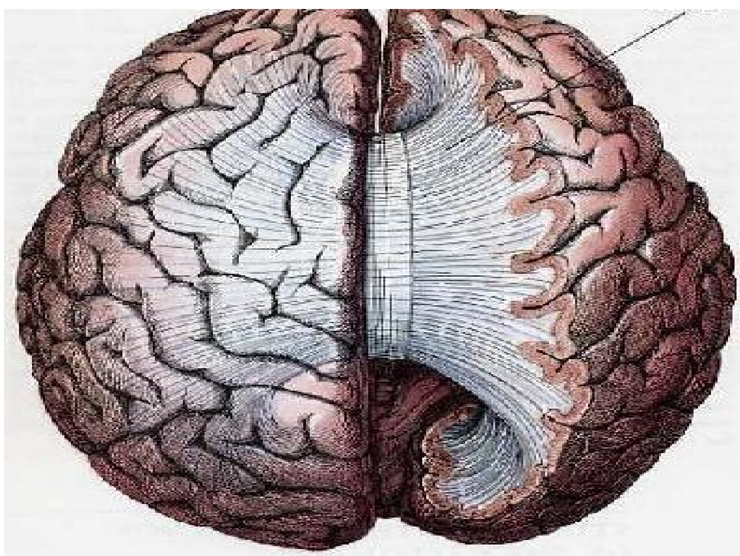


Figure 2.6 Showing brain from above, on the right side an inch or so of the top has been lopped off, with band of the corpus callosum fanning out after crossing, and joining every part of the two hemispheres .

http://hubel.med.harvard.edu/book/b34.htm

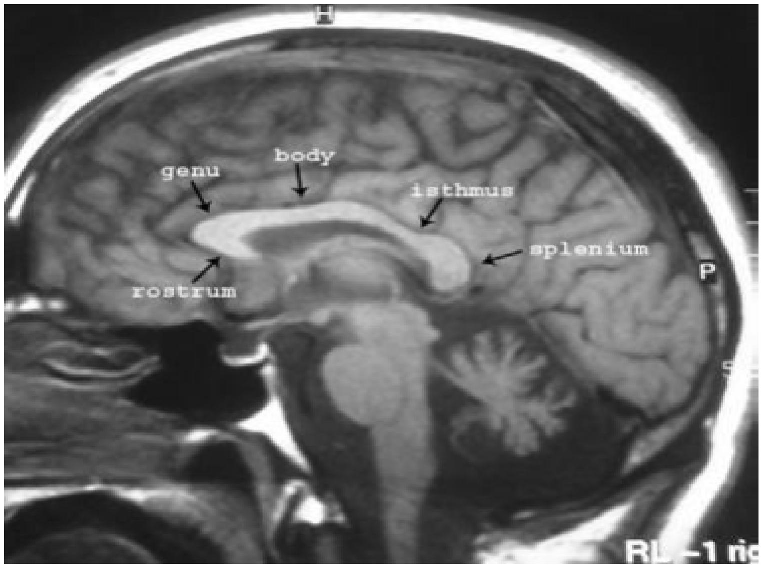


Figure 2.7 show MRI saggital image T1 with parts of corpus callosum (rostrum, genu, body and splenium)

www.emedicine.medscape.com/article/407730-overveiu#1

2.3 Physiology:

2.3.1 Physiology of brain:

The three main components of the brain-the cerebrum, the cerebellum, and the brainstem-have distinct functions. The cerebrum is the largest and most developmentally advanced part of the human brain (Sperry, 1968). It is responsible for several higher functions, including higher intellectual function, speech, emotion, integration of sensory stimuli of all types, initiation of the final common pathways for movement, and fine control of movement. The left hemisphere controls the majority of functions on the right side of the body; while the right hemisphere controls most of functions on the left side of the body the crossing of nerve fibers takes place in the brain stem. Thus, injury to the left cerebral hemisphere produces sensory and motor deficits on the right side, and vice versa. One hemisphere has a slightly more developed, or dominant, area in which written and spoken language is organized. The cerebral cortex or gray matter contains the centers of cognition and personality and the coordination of complicated movements (Sperry, 1968). The gray matter is also organized for different functions. The white matter is a net work of fibers that enables regions of the brain to communicate with each other. Such activities as speech, evaluation of stimuli, conscious thinking, and control of skeletal muscles occur here. These activities are grouped into motor areas, sensory areas, and association areas. The cerebellum, the second largest area, is responsible for maintaining balance and father control of movement and coordination. A stroke involving the cerebellum may result in a lack of coordination, clumsiness, shaking, or other muscular difficulties. The brain stem is the final pathway between cerebral structures and the spinal cord. It is responsible for a variety of automatic functions, such as control of respiration, heart rate, and blood pressure, wakeful .illness, arousal and attention (Sukkar et al. 2000).

2.3.2 Physiology of corpus callosum:

Its functional importance as the main inter hemi spheric commissure of the human brain has been well established (Sperry, 1968) and continues to be elucidated (Clarke and Zaidel 1994). More recently, though, began speculation that the CC might show global and local morphological trends in populations of interest. The major function of a corpus callosum is to enhance and maintain communication between brain hemispheres. It plays an integral role in relaying sensory, motor, and cognitive information between two hemispheres; also eye movement, maintaining the balance of arousal and attention (Sukkar et al.2000).

where the corpus callosum comes into the picture, as it facilitates this connection by acting as a bridge between the two hemispheres, and transmitting information from one hemisphere to the other. There are disputed claims about the difference in the size of the human corpus callosum in men and women and the relationship of any such differences to gender differences in human behaviour and cognition (Gupta et al.2011).

2.4 Pathology

2.4.1. Pathology of Brain:

Primary central nervous system (CNS) neoplasms are the sixth most common tumors in adults, and lesion location, intra axial or extra axial, supra tentorial or infra tentorial, tumor characterization regular or irregular or calcification, homogeneous or inhomogeneous contrast enhancement and may case mass effect, edema, and brain herniation. Neoplasms divide in primary neoplasms as Glioma, meningiomas, schwannoma, pituitary adenoma, lymphoma and secondary as metastases, cyst and tumor like lesions (Hallak et al. 2007).

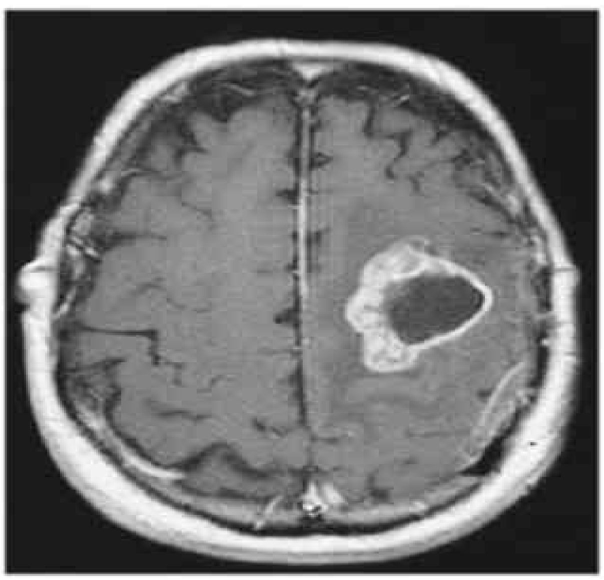


Figure 2.8 show MRI axial T1 high grade gliomas (Glioblastoma) usually show more contrast enhancement (whi te on the outside) and necrosis in the middle (Hallak et al. 2007).

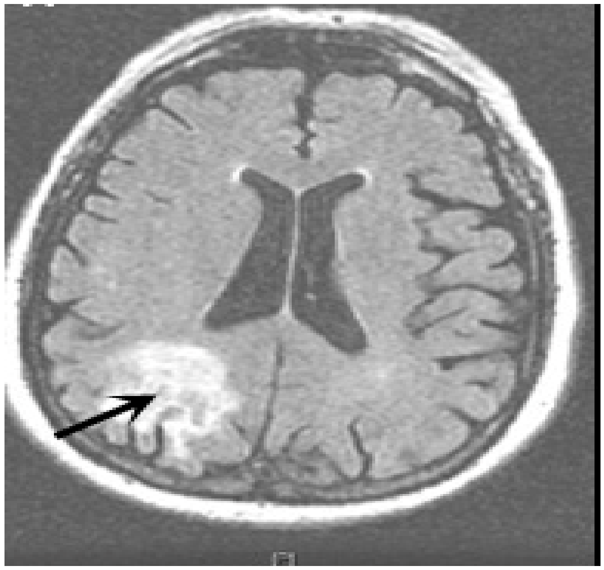


Figure 2.9 show flair MR axial image shows a right parieto-occipital area of high signal from peritumoral edema (black arrow) (Hallak et al. 2007).

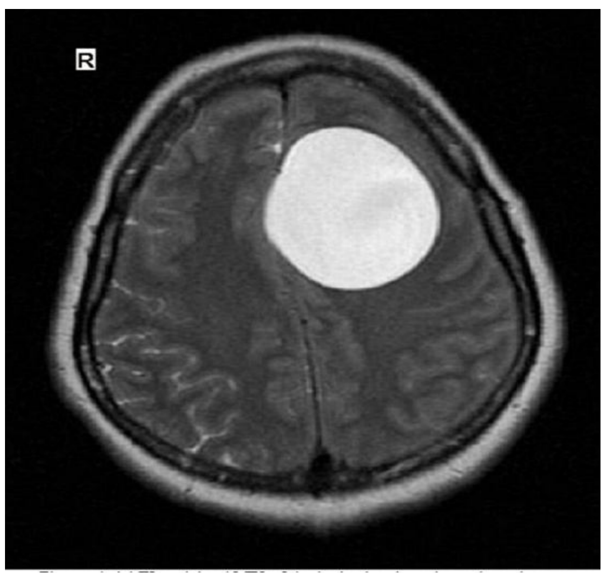


Figure 2.10 show axial T2 weighted image of the brain with large hyper intense hemispherical cystic legion (Gupta et al.2011).

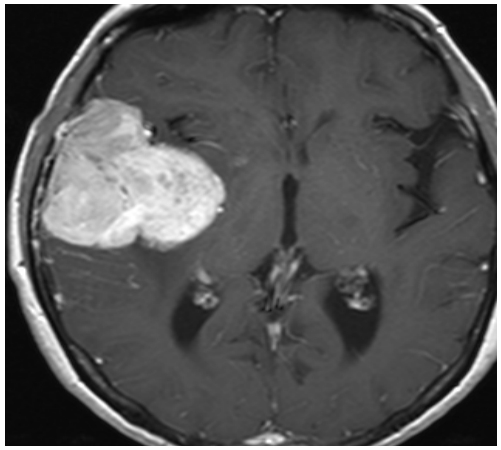


Figure 2.11 show axial T1 weighted image post-contrast of the brain with Meningioma

2.4. 2 .Pathology of corpus callosum:

2.4.2.1 Agenesis of the Corpus Callosum:

Agenesis (absence) and dysgenesis (malformation) of the corpus Agenesis of the Corpus Callosum (ACC) is a rare congenital disorder. There is a complete or partial absence of the corpus callosum. Agenesis of the corpus callosum occurs when the corpus callosum, the band of white matter connecting the two hemispheres of the brain, fails to develop normally, typically in utero . The diagnosis of callosal agenesis is by neuroimaging. Magnetic resonance imaging (MRI) is currently the imaging procedure of choice in infants and children with ACC. Other callosal disorders include dysgenesis of the corpus callosum, and hypoplasia of the corpus callosum.

The corpus callosum is important for processing and integrating sensory, motor, and cognitive information. When the corpus callosum is missing or malformed, these functions may be affected. The impact can range from subtle to severe, often depending on additional conditions that may also be present in the individual. Researchers are working to better understand the impact of these disorders and the similarities and differences among and between the different types (Hallak et al. 2007).

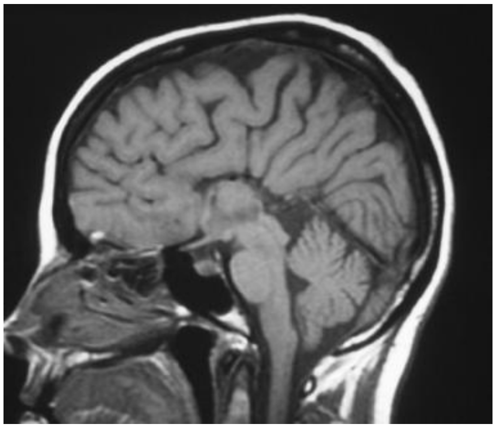


Figure 2.12 showing Sagittal T1-weighted MRI of the brain shows, agenesis. complete absence of the corpus callosum.

http://emedicine.medscape.com/article/407730-overview

2.4.2.2 Dysgenesis of the Corpus Callosum:

Dysgenesis of the corpus callosum is a relatively frequent cerebral malformation. It is usually sporadic and may be an isolated anomaly. Although it may be asymptomatic postnatally, it is considered a potential marker of neurologic impairment. The prenatal detection of other cerebral malformations indicates a poor prognosis (Hasan et al., 2012).

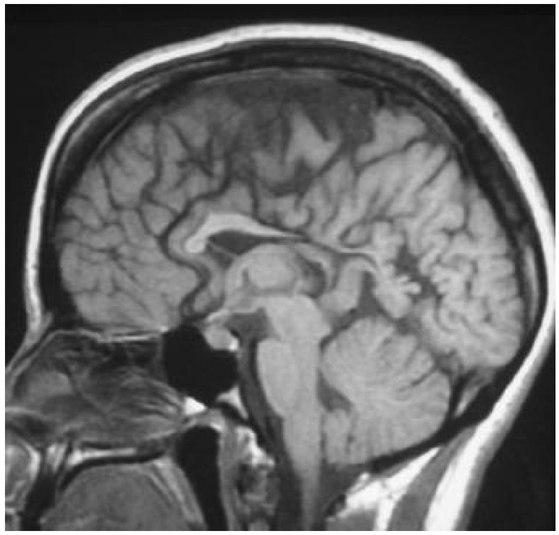


Figure 2.13 showing Sagittal T1-weighted MRI of the brain shows partial agenesis of the corpus callosum. The genu and anterior body of the corpus callosum are visualized, whereas the posterior body, splenium, and rostrum are absent.

http://emedicine.medscape.com/article/407730-overview

2.4.2.3 **Hypogenesis of the corpus callosum:**

Another term sometimes used to describe partial agenesis of the corpus callosum (Hasan et al. 2012b).

2.4.2.4 **Hypoplasia of the corpus callosum:**

The corpus callosum is present, but is abnormally thin (Di Paola et al. 2012)

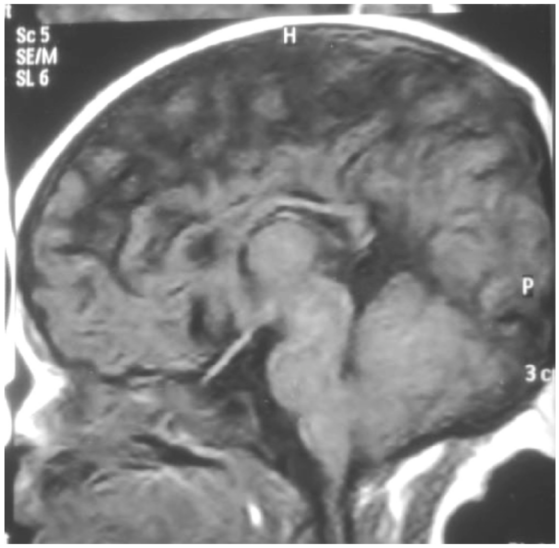


Figure 2.14 showing Sagittal T1-weighted MRI of the brain shows, hypogenesis of the corpus callosum.

http://emedicine.medscape.com/article/407730-overview

Figure 2.15 showing Sagittal T1-weighted MRI of the brain shows, hypoplasia of the corpus callosum.

http://emedicine.medscape.com/article/407730-overview

Callosal changes due to brain atrophy have been characterized in Alzheimer's disease (Tomaiuolo et al; 2007; Di Paola et al; 2010; Frederiksen et al. 2011b), which is a common form of dementia, believed to be caused by changes in the brain usually beginning in late middle age, characterized by memory lapses, confusion, emotional instability, and progressive loss of mental ability, multiple sclerosis (Hasan et al.2012b), and Huntington's disease (Di Paola et al. 2012) which is the most common type of demyelinating disease of the brain and characterized by Motor weakness, limb paresis or paralysis, abnormal sensation, visual impairment, diplopia, nystagmus, ataxia and bladder dysfunction (urinary incontinence) and so on (Sun et al. 2009). Abnormalities in callosal morphology have also been reported in neuropsychiatric diseases including schizophrenia which is a chronic and severe mental disorder that affects how a person thinks, feels, and behaves. People with schizophrenia may seem like they have lost touch with reality. Although schizophrenia is not as common as other mental disorders, the symptoms can be very disabling, bipolar disorder which is a mental disorder that causes periods of depression and periods of elevated mood , and depression which is a mood disorder that causes a persistent feeling of sadness and loss of interest , also called major depressive disorder or clinical depression, it affects feeling, thinking and behaveiour and can lead to a variety of emotional and physical problems. (Sun et al. 2009; Walterfang et al.2009b; Bearden et al. 2011). In addition, developmental disorders (Paul, 2011) including Williams syndrome which is a developmental disorder that affects many parts of the body. This condition is characterized by mild to moderate intellectual disability or learning problems, unique personality characteristics, distinctive facial features, and heart and blood vessel (Luders et al. 2007a; Sampaio et al. 2012), autism which is range of conditions characterized by challenges with social skills, repetitive behaviors, speech and nonverbal communication, as well as by unique strengths and differences (Tepest et al.2010), attention deficit

/hyperactivity disorder which is a condition in which a person has trouble paying attention and focusing on tasks, tends to act without thinking, and has trouble sitting still. It may begin in early childhood and can continue into adulthood (Luders et al. 2009; Gilliam et al.2011), and dyslexia which is disorders that involve difficulty in learning to read or interpret words, letters, and other symbols, but that do not affect general intelligence.

(Hasan et al. 2012a) are associated with callosal abnormalities. The corpus callosum is also vulnerable to diffuse axonal injury and atrophy following traumatic brain injury (Maller et al. 2010).

2.5 Texture analysis:

Texture analysis refers to the branch of imaging science that is concerned with the description of characteristic image properties by textural features. However, there is no universally agreed-upon definition of what image texture is and in general different researchers use different definitions depending upon the particular area of application (Tuceryan & Jain, 1998). Texture is defined as the spatial variation of pixel intensities, which is a definition that is widely used and accepted in the field. The main image processing disciplines in which texture analysis techniques are used are classification, segmentation and synthesis. In image classification the goal is to classify different images or image regions into distinct groups (Pietikainen, 2000). Texture analysis methods are well suited to this because they provide unique information on the texture, or spatial variation of pixels, of the region where they are applied. In image segmentation problems the aim is to establish boundaries between different image regions (Mirmehdi et al., 2008). By applying texture analysis methods to an image, and determining the precise location where texture feature values change significantly, boundaries between regions can be established. Synthesising image texture is important in three-dimensional (3D) computer graphics applications where the goal is to generate highly complex and realistic looking surfaces. Fractals have proven to be a mathematically elegant means of generating textured surfaces through the iteration of concise equations (Pentland, 1984). Conversely the ability to accurately represent a textured surface by a concise set of fractal equations has led to significant advances in image compression applications using fractal methods (Distani et al., 2006). Definition of texture features that correspond to human visual perception coarseness, contrast, directionality, line-likeness, regularity, roughness. Also analysis of texture parameters is a useful way of increasing the information obtainable from medical images. It is an ongoing field of research, with applications ranging from the segmentation of specific anatomical structures and the detection of lesions, to differentiation between pathological and healthy tissue in different organs. Texture analysis uses radiological images obtained in routine diagnostic practice, but involves an ensemble of mathematical computations performed with the data contained within the images. The analysis of texture parameters is a useful way of increasing the information obtainable from medical images. It is an ongoing field of research, with applications ranging from the segmentation of specific anatomical structures and the detection of lesions, to differentiation between pathological and healthy tissue in different organs. Texture analysis uses radiological images obtained in routine diagnostic practice, but involves an ensemble of mathematical computations performed with the data contained within the images. In this article we clarify the principles of texture analysis and give examples of its applications, reviewing studies of the technique (Castellano et al.2004). The texture of images refers to the appearance ,structure and arrangement of the parts of an object within the image. Images used for diagnostic purposes in clinical practice are digital. A two-dimensional digital image is composed of little rectangular blocks or pixels (picture elements), and a three-dimensional digital image is composed of little volume blocks called voxels (volume elements); each is represented by a set of coordinates in space, and each has a value, representing the grey-level intensity of that picture or volume element in space. Since most medical images are two-dimensional we will restrict the discussion to pixels, bearing in mind that the extension to voxels and volumetric images is straight forward. We may attribute the texture concept in a digital image to the distribution of grey-level values among the pixels of a given region of interest in the image (Castellano et al.2004).

2.6 MRI basic and advanced techniques in brain and corpus callosum imaging :

An MRI scanner uses a strong magnetic field and radio waves to create pictures of the tissues and other structures inside the brain, . Sometimes a dye, or tracer, such as gadolinium may be introduced via a vein in the arm, to improve contrast in the image. Images can be enhanced by differences in the strength of the nuclear magnetic resonance signal recovered from different locations in the brain. The relaxation times, T1 and T2, are measured after the scanner's pulse sequence, and can be chosen to look at specific tissue within the brain. For example, at a T2setting, water and fluid containing tissue appears bright, whilst fat containing tissue is dark, and this can be used to distinguish damaged tissue from normal tissue. A T1setting gives a clear image for the contrast between white and grey matter in the brain.. The patient lies on a couch which slides into the tunnel. It is quite noisy so the patient is given headphones with music of their choice, and has to keep still for 15 to 40 minutes as the tiny radio wave signals are picked up by the computer. It is entirely painless, but children may require a general anesthetic to keep them still for long enough. The radiographer needed to know if the patient has any metal in their body such as a metal skull plate, inner ear implants, pacemaker, artificial joints, or screws or pins holding bone fracture repairs. The patient may resume normal activities immediately after the scan, and the radiologist studies the pictures and sends a report to the doctor (Catherine Westbrook, 2008).

Figure 2.16 show MRI machine

Figure 2.17 show MRI head coil

2.6.1 Common indications :

- Primary tumour assessment and/or metastatic disease

- AIDS (toxoplasmosis)
- Infarction (cerebral vascular accident (CVA) versus transient
- ischaemic attack (TIA))
- Haemorrhage
- Hearing loss
- Visual disturbances
- Infection
- Trauma
- Unexplained neurological symptoms or deficit
- Preoperative planning

2.6.2 Equipment :

- Head coil (quadrature or multi-coil array)
- Immobilization pads and straps
- Earplugs/headphones
- High-performance gradients for EPI, diffusion and perfusion imaging

2.6.3 Patient positioning :

The patient lies supine on the examination couch with their head within the head coil. The head is adjusted so that the inter-pupillary line is paral-lel to the couch and the head is straight. The patient is 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 (Catherine Westbrook, 2008).

2.6.4 Suggested protocol :

2.6.4.1Sagittal SE/FSE/incoherent (spoiled) GRE T1:

Medium slices/gaps are prescribed on each side of the longitudinal alignment light from one temporal lobe to the other. The area from below the foramen magnum to the top of the head is included in the image.

L 37 mm to R 37 mm

2.6.4.2Axial/oblique SE/FSE PD/T2:

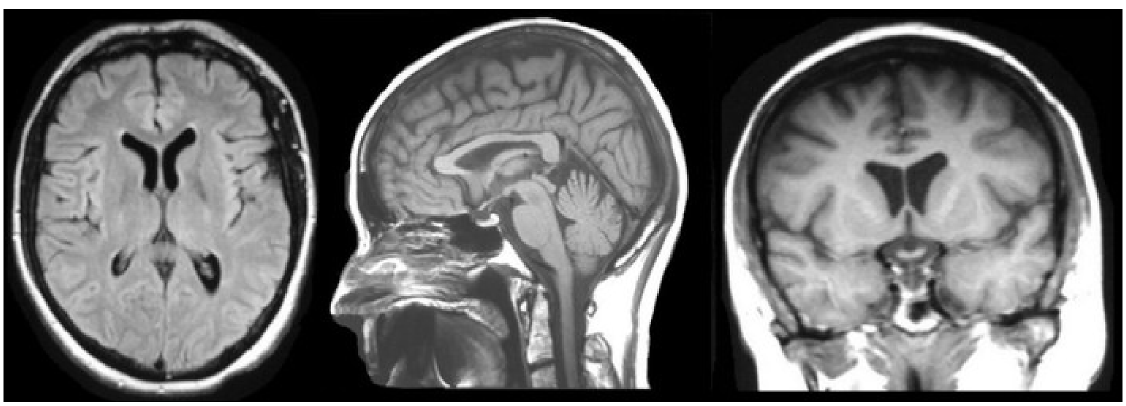
Medium slices/gaps are prescribed from below the foramen magnum to the superior surface of the brain. Slices may be angled so that they are parallel to the anterior–posterior commissure axis.

2.6.4.3Coronal SE/FSE PD/T2:

As for axial PD/T2, except prescribe slices from the cerebellum to the frontal lobe.

Magnetic resonance imaging (MRI) examinations of the brain can be performed with several coil types, depending on the design of the MRI unit and the information required , recently, phased-array head coils have become the standard of practice for state-of-the-art high-resolution MRI of the brain . An MRI examination of the brain begins with one (or more) fast localizer scans (also known as scout or survey images). For this purpose, we use fast sequences (obtained in seconds), and ideally obtain slices in three orthogonal imaging planes. On the basis of the initial localizer images, additional localizer scans are per-formed, if needed, until the operator is satisfied that imaging sequences can be started in true sagittal, coronal, or axial planes (parizel et al. (2010). The positioning of sagittal images is obvious, due to the left–right symmetry of the brain. Sagittal images are placed on a coronal localizer image if the head is not rotated. An axial plane can also be used, provided there is no left–right tilt of the head. In clinical practice, the positioning of sagittal images is self-explanatory. Ideally, on the mid sagittal image, the following anatomical landmarks should be identified corpus callosum (over its entire length), Sylvian aqueduct, fourth ventricle, and cervical spinal cord (Catherine Westbrook, 2008).

MRI MR also provides useful information concerning white matter involvement and MRI is regarded as the best method to obtain crosssectional area and shape information of corpus callosum. In addition, MRI is fast and safe, without any radiation exposure to the subject such as with X-ray, CT. Since manual tracing of corpus callosum in MR images is time consuming, operator-dependent (Gupta et al.(2011). Also MRI is one of the most commonly used tests in neurology and neurosurgery. MRI provides exquisite detail of brain, spinal cord and vascular anatomy, and has the advantage of being able to visualize anatomy in all three planes: axial, sagittal and coronal .



a b c

Figure 2.18 showing MRI has the advantage of being able to visualize anatomy in all three planes: (a)axial T1 , (b) sagittal T1and (c) coronal T1 http://casemed.case.edu/clerkships/neurology/Web%20Neurorad/MRI%20Basics.htm

2.6.5 Diffusion MRI(dMRI) and tractography :

When the diffusion of water along the three orthogonal directions of the magnet (X, Y and Z) is measured and the average obtained, only isotropic diffusion information is acquired, that is, diffusion that is random in direction. In the brain, this is seen in grey matter. In white matter, the structure of the tissue 'orders' the diffusion. In white matter, diffusion is ordered along the white matter tracts. This type of ordered diffusion is referred to as anisotropy (anisotropic diffusion). In order to image an isotropic diffusion, diffusion in more than three axes is measured. In physics, a tensor is basically motion as a function of direction. DTI is essentially imaging diffusion that is ordered in direction (anisotropic rather than isotropic). At a minimum, DTI must measure the diffusion along at least six axes. In clinical practice, 12 or more directions are measured. Due to a loss in SNR as the number of directions measured increases, DTI is particularly useful at high field strengths such as 3 T. DTI is currently used for mapping white matter tracts as fractional anisotropy (FA) maps, or as tractography images. Modeling provide important information about the corpus callosum fibre tracts and the cortical regions they connect. These dMRI data of trans callosal fibre tracts in normal brains resulted in a new organizational scheme that describes corpus callosum structure, and suggested that much more of the corpus callosum is involved in pre motor and supplementary motor coordination than previously thought (Catherine Westbrook, 2008).

When the diffusion of water along the three orthogonal directions of the magnet (X, Y and Z) is measured and the average obtained, only isotropic diffusion information is acquired; that is diffusion that is random in direction. In the brain this is seen in grey matter. In white matter, the structure of the tissue 'orders' the diffusion. In white matter diffusion is ordered along the white matter tracts. This type of ordered diffusion is referred to as anisotropy (anisotropic diffusion). In order to image anisotropic diffusion, diffusion in more than three axes is measured. In physics, a tensor is basically motion as a function of direction. DTI is essentially imaging dif-fusion that is ordered in direction (anisotropic rather than isotropic). At a minimum, DTI must measure the diffusion along at least six axes. In clin ical practice twelve or more directions are measured. Due to a loss in SNR as the number of directions measured increases, DTI is particularly useful at high field strengths such as 3 T. DTI is currently used for mapping white matter tracts as tractography images (Catherine Westbrook, 2008).

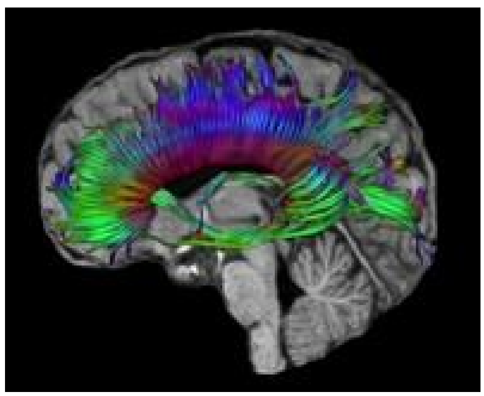


Figure 2.19 show Data from diffusion tensor imaging (DTI) was seeded to show various tractographic assessments of the wide bundle of neural fibers found in the corpus callosum.

http://bioengineering.rice.edu/Content.aspx?id=2147483699

2.7 Previous studies :

Mourgela et al. (2007) studied gender and age-related differences in the dimensions of the corpus callosum and brain, using MRI brain images. The author also measured the longitudinal and vertical dimensions of the brain, in order to define the relative topographic locations of the corpus callosum within the brain, and to search for any sex- and age-related differences in dimensions or relative position. The study consisted of 35 human brain MRI examinations free from pathology. For measurement purposes a mid-sagittal view of the cerebral hemispheres were used as follows: (a) from the frontal to the occipital pole (b) from the superior to the inferior surface of the brain, including the cerebellum, (c) from the frontal pole to the genu; and (d) from the occipital pole to the splenium. These measurements were conducted using a straight-line method of measurement. Their results showed that the mean value for the longitudinal dimension of the brain orientated from the frontal to occipital pole was 15.25±0.80 cm, while the mean value for the longitudinal dimension of the corpus callosum was 6.91±0.51 cm. The mean value for the longitudinal dimension of the genu was 2.13±0.38 cm the splenium 0.74±0.16 cm. Only the inter-sex difference in mean value for cerebellum (male = 13.36±0.65 cm, female =12.75±0.72 cm) was statistically significant (p=0.016). In terms of age, there was a statistically-significant decrease in the longitudinal dimensions of the corpus callosum after age 45. Callosal size in older patients should be expected, because of the generalized atrophy of cortical neurons that occurs with advancing age. Atrophy not only causes a decrease in the amount of gray matter, but also a loss of white matter. This age-related decrease in neuronal size, number of myelinated fibers, and amount of myelination likely is responsible for the age-related decrease in size of the corpus callosum .

Mohammadi et al. (2011) measured the corpus callosum using MRI in the north of Iran; to determine the longitudinal and vertical dimensions of the brain and the dimensions of various parts of the corpus callosum by MRI. Measurement were taken similar to Mourgela et al. (2007). The mean value for the longitudinal dimension of the brain (AB) was 16.12±0.081 cm, while the mean value for the longitudinal dimension of the corpus callosum (from anterior most point of corpus callosum to its posterior most point), was 7.06± 0.052 cm. while the mean value for the longitudinal dimension of the genu and the splenium was 2.35±0.017 cm, and 1.41±0.010 cm respectively. As well as the distance between the genu and the frontal pole had a mean value of 3.68±0.034 cm, while the distance from the splenium to the occipital pole was 5.580±0.052 cm. Regarding age, there was a statistically-significant increase in the longitudinal dimensions of the corpus callosum. The mean length of the corpus callosum was 7.25±0.08 cm in those subjects who were 45 years old and more. It was 7.19±0.06 cm in those who were 30-44 years old while in those younger than 30 years it was 6.82±0.10 cm with $p = 0.001$.

Laissy J. P. et al (1993) in their study midsagittal MR measurements of the corpus callosum in healthy subjects and diseased patients, they found the mean CC midsagittal surface area was 6.36 cm^2, and mean length was 70.6 mm. Mean diameters for the genu, the body, and the splenium were respectively 9.6, 6, and 10.8 mm. The MISS was 143.19 cm^2 and the CC/MISS ratio 4.46%.Average CC/subcutaneous fat ratio was 0.7 (SD, 0.06). CC/CSF ratio was 3.45 (SD, 0.5) and elderly controls >70 years and AIDS patients displayed significant CC atrophy.

Ronald A. Rauch and J. Randy Jinkins (1995) in their study variability of corpus callosal area measurements from midsagittal MR images: effect of subject placement within the scanner , they found the mean callosal area for all subjects was 5.7 cm^2. The average SD for each series of measurements from one image made by one observer was 0.20 cm^2. With these data, the calculated 95% confidence interval for any one measurement was 62.5%. The average SD for mean callosal areas measured from different images of the same subject was 0.26 cm^2. With these data, the calculated 95% confidence interval for any one image's measurement was 63.7%.

Giedd J.N.et al(1996) studied A quantitative MRI study of the corpus callosum in children and adolescents, in their study they found total corpus callosum area increases in a robust and linear fashion from ages 4 to 18 (slope = 13.1 mm2/year, P= 0.0001 and slope = 11.1 mme/year, P= 0.0001 for females and males, respectively). The slopes do not differ between males and females on any region. The age related increases were driven by the four posterior-most regions which showed highly significant changes (P _< 0.005) for both sexes.

(Gupta et al. (2011) studied sexual dimorphism of splenial thickness of corpus callosum, in their study thickness of splenium was measured at the level of its maximum thickness horizontly & compared, the data has been placed into groups depending on age and sex of patients and analyzed, they found that there is no significant difference in thickness of splenium as far as age and sex is concerned. Variations observed are more likely to be due to individual difference.

Aydlnlioglu et al. (1996) studied the relationship of sex differences to the anatomy of corpus callosum in the living human being for turkish population, they examined the MRIs of seventy adults for possible differences in the shape and size of the corpus callosum between different sexes.. There were30 women and 40 men with ages ranging from 20 to 55 years (mean: 34 years). The magnetic resonance images of the midsagittal plane of each human brain was examined by a 0.5 tesla MRI unit at the radiology department , they found that the area of the mid sagittal section of the corpus callosum, particularly in the region of the splenium was found to be greater in women than in men. The magnetic resonance imaging of seventy adults was examined and showed the same association previously observed, between sex differences and area of the corpus callosum and its splenium. The quantitative results supported a relationship between variations in callosal anatomy and sex differences in human beings.

Mitchell et al. (2003) studied reliable callosal measurement: population normative data confirm sex-related differences in American, their study was applied to 100 healthy adults, 44 men with mean age, 31.2 years, 36 right handed and 56 women with mean age, 33.8 years, 51 right handed, were imaged and age range for the group,14–68 years; mean, 32.6 years ± 12.3, drawn from a community population to determine the effects of sex, age ,and handedness on corpus callosum area and to assess the relationship between callosal area and cerebral volume .they found that The mean corpus callosum area was 6.27 cm^2 ± 0.90, the mean corpus callosum area was 6.55 cm^2 ± 0.98 in men and 6.06cm^2 ± 0.79 in women, with a significant sex difference ($P < .01$). Men had a greater cerebral volume than women ($P < .001$) .Regression analysis of corpus callosum area and cerebral volume revealed a significant, though small positive linear correlation, r^2= 0.15. The sex difference persisted but was reversed with women having a proportionately larger callosal area, $P = .02$.

Gupta et al. (2009) studied normative data of corpus callosal morphology in a north-west indian population- an autopsy and MRI study in 30 adults ,19 males and 11 females were include , the study was conducted to determine

the morphometric measurements of the CC in normal adult population in northwest region of India. 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. In addition, deviation from the normal parameters in various neurological diseases affecting the CC and relative structure can be studied, they conclude that the length CC was 6.98cm (males) and 6.86cm (females) while the corresponding values in theMRI group were 7.57 cm and 7.1 cm. The height CC was 2.15cm
(males) and 1.92 cm (females) in the preserved group, and 3.27 cm (males) and 2.59 cm (females) in the MRI group. The splenial width values were 1.12cm (males) and 1.01 cm (female) in the preserved brains while the corresponding MRI values were 1.15 cm and 1.17 cm. The values of different CC parameters observed were almost similar to the values reported in the other two Indian studies. However, Indian values were found to be more than the Japanese values for length, height and most of the widths of CC. The length and width of CC were found to be less than those of Caucasian population. Generation of this data will help incomparing.
The CC structure of different sex and ages, to study variations from the normal and may help in surgical planning.
Gupta et al. (2008) in their study age and sex related variations in Corpus Callosal morphology in Indian population for comprehensive data 44 preserved human brains 22 male and 22 female. Morphometric measurements of the CC and its sub regions were taken at the mid sagittal level in both the groups and subjected to statistical analysis, they conclude that most of the CC parameters were found to be similar in both sexes in both the autopsy and the MRI group, larger CC length in males as compared to females in the MRI group, this is possibly related to larger brain size in

males, the width of the anterior half of CC decreased with increasing age in males, but not in females in preserved brains, the width of the anterior half of the CC was more in younger males than in older males i.e. the CC width decreased with age in males, but not in females .the decrease in the width of CC with age is consistent with reported decline in dichotic listening and binaural processing skills with age occurring earlier in men than in woman by (Bellis & Wilber 2001).

In study by (Tuceryan and Jain, 1998) they studied clinical applicability of MRI texture analysis. A total of 220 participants were included in this thesis. The materials include a study on non-Hodgkin lymphoma, representing soft tissue imaging with malignant disease treatment monitoring; and two studies on central nervous system diseases, mild traumatic brain injury and multiple sclerosis. A musculoskeletal imaging study investigated load-associated physiological changes in healthy participants' bones. Furthermore, manual Region of Interest (ROI) definition methods and the selection of MRI sequences for analyses of visible and non-visible lesions were evaluated. In summary, this study showed that non-visible lesions and physiological changes as well as visible focal lesions of different etiologies could be detected and characterized by texture analysis of routine clinical 1.5 T scans. The details of MRI sequence selection and ROI definition in this study may serve as guidelines for the development of clinical protocols.

Kovalev et al. (2001) in their study the effect of trauma on texture features in cerebral tissue in mild traumatic brain injury , they imaged 42 patients by using 1.5 T MRI within three weeks of onset of trauma, texture analysis was performed on the area of cerebral white matter and in different segments of corpus callosum (CC) which have been found to be sensitive to damage. The same procedure was carried out on a control group of ten healthy volunteers.

Patients' texture analysis data was compared with the texture analysis results of the control group comparing the amount of statistically significantly differing texture analysis data parameters between the left and right sides of the cerebral tissue and comparing the most discriminative parameters. They conclude that texture analysis revealed significant changes in texture parameters of cerebral tissue between hemispheres and CC segments in traumatic brain injury patients. Texture analysis may serve as a novel additional tool for detecting the conventionally invisible changes in cerebral tissue in mild traumatic brain injury and help the clinicians to make an early diagnosis.

Texturally corpus callosum tissues in MRI can be identified using several types of textural measures. Texture analysis is a branch of image processing, which attempts to convey "texture" information from digital images, such as magnetic resonance images (MRI). Machado-Joseph disease affects mainly cerebellum and brainstem, but recent studies have shown that other cerebral structures may also be affected. Oliveira et al. (2010) used MRI-texture analysis of corpus callosum, thalamus, putamen, and caudate in Machado-Joseph disease; to investigate subtle structural abnormalities in corpus callosum thalami, putamen, and caudate nuclei of patients with Machado-Joseph disease versus normal tissues using textural analysis. Eighteen healthy volunteers and 18 patients with Machado-Joseph disease were studied (mean age at disease onset = 34.7 years; disease duration = 9.6 years; mean expanded CAG in the Machado-Joseph disease gene = 73). A textural analysis approach based on the gray-level co occurrence matrix was applied to T1-MRI. Regions of interest were manually segmented for each subject, and texture parameters were computed for each of the aforementioned anatomical structures. The result showed that there are differences between the 2 groups for the caudate nuclei, thalami, and putamen. No differences were found for the corpus callosum.

Herlidou-Même et al. (2003) stated that normal brain and intracranial tumors texture analysis when performed in three different MRI units on T1 and T2-weighted MR images from 10 healthy volunteers and 63 patients with histologically confirmed intracranial tumors. The goal of their study was a multicenter evaluation of the usefulness of this quantitative approach for the characterization of healthy and pathologic human brain tissues (white matter, gray matter, cerebrospinal fluid, tumors and edema). Each selected brain region of interest was characterized with both its mean gray level values and several texture parameters. Multivariate statistical analyses were then applied in order to discriminate each brain tissue type represented by its own set of texture parameters. Texture analysis was previously performed on test objects to evaluate the method dependence on acquisition parameters and consequently the interest of a multicenter evaluation. Even obtained on different sites with their own acquisition routine protocol, MR brain images contain textural features that can reveal discriminant factors for tissue classification and image segmentation. It can also offer additional information in case of undetermined diagnosis or to develop a more accurate tumor grading.

Chapter Three

Materials and methods

3.1 Materials:

This study was carried out using MRI scanner of 1.5 Tesla (Toshiba) in the period from August 2014– 2017.

3.1.1 Design:

This study is a descriptive cross-sectional study conducted at Modern Medical Center Royal Care International Hospital.

3.1.2 Population:

This study included male and female with normal corpus callosum their age ranged between <10>60years. Patients were excluded only when the pathologic process affected, or theoretically could affect, the corpus callosum (e.g., hydrocephalus or tumor) and when the entire corpus callosum was not on a single slice as a consequence of an oblique imaging plane. Magnetic resonance images were eliminated if there was any visible evidence of deviation from the midsagittal plane.

3.1.3 Sample size and type:

A convenient sample type were adapted, where a total of 233 patients (126 male and 107 female) present for Brain MRI scan were included in the study in respect to the inclusion criteria.

3.2 Methods:

3.2.1 Stander MRI Techniques:

Patient under went to MRI department for MRI brain, use the head coil with a sheet on the table, remove dentures, hair clips, hair combs, earrings, nose rings, necklaces, position the patient so their head and neck are relaxed, but without rotation in either plane, centre the field of view on the nasion in the midline, making minor adjustments for baseline tilt.

3.2.2 Measurement done and image interpretation:

Data collection sheet were used to collect data about demographic characteristics (gender and age). In this study various parameters of corpus callosum were measured in Sudanese at the mid-sagittal plane of T1 MR Images as described by Figueira et al. (2007). The considered variables were:-

- Fronto occipital maximum length.
- Thickness of various parts of corpus callosum at its maximum level (rostrum, genu, body/trunk and splenium).
- Greatest Anteroposterior Diameter Of corpus callosum.
- Fronto-Corpus Callosum length (Distance of corpus callosum from frontal pole) and Occipito-Corpus

Callosum length (occipital pole of cerebral hemisphere).

- Corpus callosum index (CCI)

Corpus callosum index (CCI) was obtained on a conventional best mid saggital T1whigted image, using a simple orthogonal semi-automated system, by drawing a straight line at greatest anteroposterior diameter of CC and a perpendicular at its midline, owing to points genue maximum thickness, trunk maximum thickness and maximum thickness length of CC were measured and normalized to its greatest anteroposterior diameter (from genu to splenium), CCI was found for each cases, one by one, from the calculated measurements by Formula applied previously by Mehmet et al (2012).

Corpus callosum index (CCI) = (Genue maximum thickness + Trunk maximum thickness + Splenium

maximum thickness /(CC greatest anteroposterior diameter).

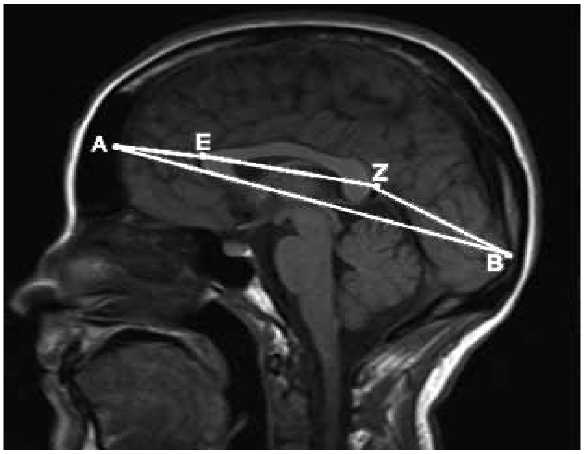


Figure 3.1 Sigittal T1 image showing measurement of various parts of corpus callosum. AB: Fronto-Occipital length, EZ: Corpus Callosum length, AE: Fronto-Corpus Callosum length, ZB: Occipito-Corpus Callosum length

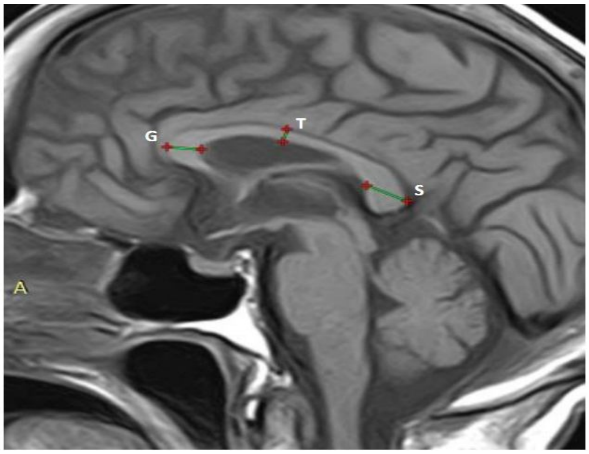


Figure 3.2 Sigittal T1 image (TR: 676, TE: 10, slice thickness: 5.3 mm) of male patient (70 Years) showing measurement of various parts of corpus callosum. G: the Genu, T: the Trunk, S: the Splenium .

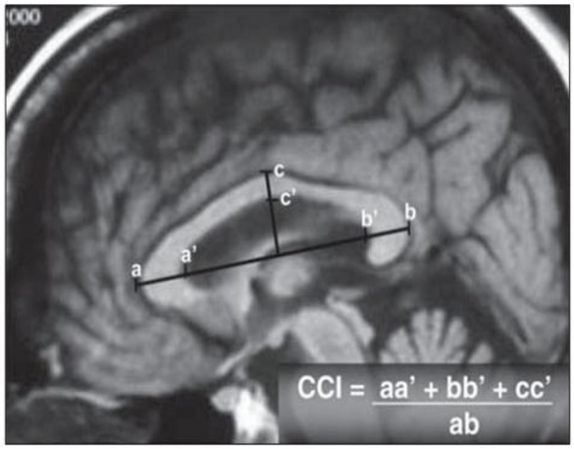


Figure 3.3 Determination of corpus callosum index, using a "best" midsagittal slice on a T1W brain MR (Mehmet et al .2012).

3.2.3 Method of data analysis for data of texture analysis method:

The Obtained data were transferred to SPSS (ver. 16.0) programme and were analyzed and presented as mean, standard deviation, and normal curve as well as significant differences between the different age groups were tested.

-Linear discriminant analysis using stepwise will be applied to select the optimum subset of the textural feature.

- Using linear discrimination analysis .

Regarding texture analysis , this study was include male and female with normal corpuscallosum their age ranged between < 10 >60 years, a convenient sample type were adapted, where a total of 233 patient present for Brain MRI scan. Patients were excluded only when the pathologic process affected, or theoretically could affect, the corpus callosum (e.g., hydrocephalus or tumor) and when the entire corpus callosum was not on a single slice as a consequence of an oblique imaging plane. Magnetic resonance images were eliminated if there was any visible evidence of deviation from the midsagittal plane.

3.2.4 Texture analysis techniques: Patient under went to MRI department for MRI brain , use the head coil with a sheet on the table, remove dentures, hair clips, hair combs, earrings, nose rings, necklaces , position the patient so their head and neck are relaxed, but without rotation in either plane , centre the field of view on the nasion in the midline, making minor adjustments for baselinetilt.probability,tocalculatetexture.Themainadvantageofthisapproachis itssimplicitythroughtheuseofstandarddescriptors(e.g.meanandvariance)tochar acterizethepowerof the approach for discriminating between unique textures is limited in certain applications because the method does not consider the spatial relationship ,and correlation, between pixels .For any surface ,or image , grey levels are in the range 0≤i≤Ng 1, where Ngis the total number of distinct grey-levels . If N (i) is the number of pixels with intensity I and M is the total number of pixels in an image, it follows that the histogram, or pixel occurrence probability, is given by,

$$P(i) = \frac{N(i)}{M}$$

In general, seven features commonly used to describe the properties of the image histogram, and there for image texture, are computed. These are: mean; variance; coarseness; skewness; kurtosis; energy; and entropy.

3.2.4.1Texture analysis interpretation:

Analyzing the images with Interactive Data Language IDL software to measure the grey level variation of MRI images, classify the MRI corpuscallosum to genu, trunk and spleninum, density the features of the classified regions of the whole images (as raw data) were classified furthers using linear discriminate analysis.

3.2.4.2 Statistical Methods

First Order Statistics: FOS can be used as the most basic texture feature extraction methods, which are based on the probability of pixel intensity values occurring in digital images. The parameters in the following statistical formulas are xi, the intensity value of pixel i, N, the total number of pixels, maxV , the maximum intensity value within a patch and Hi, the histogram of an image patch.

Chapter Four

Results

Table 4.1: Descriptive statistics of the dimensions of Corpus Callosum (CC) and Brain in Sudanese population.

Descriptive Statistics					
Morphometric index	N	Min(mm)	Max(mm)	Mean(mm)	STDV
Fronto Occipital Length	233	70.00	196.00	165.03	11.39
CC greatest anteroposterior diameter	233	52.00	163.00	74.33	7.49
Rostrum Maximum Thickness	233	0.30	3.00	1.24	.50
Genu Maximum Thickness	233	5.00	18.00	11.56	2.39
Trunk Maximum Thickness	233	2.70	9.00	6.21	1.34
Splenium Maximum Thickness	233	3.70	15.00	10.64	2.18
Fronto-Corpus Callosum Length	233	3.00	51.20	36.32	4.22
Occipito-Corpus Callosum Length	233	40.00	72.00	55.98	5.42
Corpus Callosum Index	233	0.034	0.514	0.37	0.06
CC greatest anteroposterior diameter /Fronto occipital length ***(Ratio)is*** **74.33/165.03=0.45**					

Table 4. 2: Descriptive statistics of the Brain dimensions in Sudanese population classified according to age.

Descriptive							P-value
		N	Mean	STDV	Min	Max	
Fronto Occipital Length	<10	24	154.04	13.06	132.00	177.00	0.000
	11-20	33	163.67	10.49	143.00	196.00	
	21-30	37	166.37	8.44	153.00	190.00	
	31-40	49	168.85	7.46	154.00	186.00	
	41-50	40	164.92	16.71	70.00	187.00	
	51-60	17	166.19	8.64	153.00	180.00	
	>60	33	166.71	6.84	154.00	180.00	
	Total	233	165.03	11.39	70.00	196.00	
Fronto-Corpus Callosum Length	<10	24	38.78	3.52	32.00	44.00	.015
	11-20	33	36.91	3.71	29.00	47.00	
	21-30	37	36.20	3.27	31.00	48.00	
	31-40	49	34.89	5.49	3.00	42.00	
	41-50	40	36.22	3.10	30.00	46.00	
	51-60	17	37.17	5.84	32.00	51.20	
	>60	33	35.89	3.39	29.00	44.00	
	Total	233	36.32	4.22	3.00	51.20	
Occipito-Corpus Callosum Length	<10	24	55.45	6.55	43.00	65.00	.126
	11-20	33	56.54	5.71	44.00	67.00	
	21-30	37	56.54	5.21	47.00	72.00	
	31-40	49	57.50	4.88	48.00	68.00	
	41-50	40	54.62	5.08	44.00	63.00	
	51-60	17	53.91	5.11	46.60	63.00	
	>60	33	55.63	5.46	40.00	67.00	
	Total	233	55.98	5.42	40.00	72.00	

Table 4.3: Dimensions of Corpus Callosum compartments in Sudanese population classified according to age

Morphometric index	Age Class	N	Mean	Std.	Min	Max	P-value
Corpus callous antero posterior diameter (mm)	<10	24	61.50	6.69	52.00	80.00	0.000
	11-20	33	70.80	6.88	55.00	84.00	
	21-30	37	75.18	5.88	63.00	87.00	
	31-40	49	77.58	5.34	66.00	89.00	
	41-50	40	79.77	14.26	67.00	163.00	
	51-60	17	76.13	5.19	67.00	88.00	
	>60	33	76.93	5.30	67.00	92.00	
	Total	233	74.76	9.45	52.00	163.00	
Rostrum maximum thickness (mm)	<10	24	.77	.41	.30	2.40	0.000
	11-20	33	1.07	.43	.50	2.40	
	21-30	37	1.34	.43	.80	2.50	
	31-40	49	1.52	.46	1.00	3.00	
	41-50	40	1.31	.45	.80	2.60	
	51-60	17	1.35	.59	.50	2.80	
	>60	33	1.09	.48	.50	2.40	
	Total	233	1.24	.50	.30	3.00	
Genu maximum thickness (mm)	<10	24	8.81	1.97	5.00	13.00	0.000
	11-20	33	10.90	2.15	7.60	15.00	
	21-30	37	12.68	1.71	8.00	16.00	
	31-40	49	13.03	2.20	7.00	18.00	
	41-50	40	12.45	1.66	9.00	16.00	
	51-60	17	10.98	2.11	7.00	14.00	
	>60	33	10.01	1.85	7.00	15.00	
	Total	233	11.56	2.39	5.00	18.00	
Body maximum thickness (mm)	<10	24	4.63	1.37	2.70	7.50	0.000
	11-20	33	5.88	1.29	4.00	8.00	
	21-30	37	6.75	.96	4.40	9.00	
	31-40	49	6.83	.98	4.70	9.00	
	41-50	40	7.05	.86	6.00	9.00	
	51-60	17	5.99	.75	5.00	7.00	
	>60	33	5.25	1.23	3.00	9.00	
	Total	233	6.21	1.34	2.70	9.00	
Splenium maximum thickness (mm)	<10	24	7.88	1.57	4.00	10.00	0.000
	11-20	33	10.21	2.55	3.70	15.00	
	21-30	37	11.28	1.69	7.40	15.00	
	31-40	49	11.18	1.85	6.00	14.00	
	41-50	40	11.92	1.73	8.00	15.00	
	51-60	17	11.32	1.73	8.00	14.00	
	>60	33	9.66	1.64	7.00	13.00	
	Total	233	10.64	2.18	3.70	15.00	

Corpus callosum index	<10	24	.34	.05	.267	.47	0.000
	11-20	33	.37	.08	.034	.51	
	21-30	37	.41	.04	.310	.50	
	31-40	49	.40	.04	.287	.48	
	41-50	40	.39	.07	.038	.50	
	51-60	17	.37	.04	.314	.45	
	>60	33	.33	.05	.236	.46	
	Total	233	.37	.06	.034	.51	

Table 4.4: Morphometric index/ chart established for brain and corpus callosum dimensions in Sudanese population for both genders at similar age classes

Morphometric index	**Gender**	**Age Classes**						
		<10	**11-20**	**21-30**	**31-40**	**41-50**	**51-60**	**>60**
Fronto Occipital Length /(mm)	Male	154.42 ±13.5	169.3 ±5.35	171.31 ±8.50	171.30 ±7.19	163.05 ±24.76	170.21 ±7.95	167.60 ±6.98
	Female	152.60 ±12.17	161.21 ±11.30	162.61 ±6.29	165.00 ±6.30	166.30 ±6.68	162.62 ±7.97	163.42 ±5.50
CC greatest anteroposterior diameter /(mm)	Male	62.00 ±7.19	70.40 ±7.47	75.18 ±6.41	78.26 ±5.19	84.05 ±20.83	76.66 ±6.82	76.69 ±5.71
	Female	59.60 ±4.33	70.98 ±6.77	75.19 ±5.61	76.50 ±5.55	76.60 ±4.49	75.66 3.57	77.85 ±3.57
Rostrum Maximum Thickness /(mm)	Male	.80 ±.44	1.13 ±.49	1.42 ±.53	1.54 ±.39	1.46 ±.454	1.40 ±.79	1.08 ±.47
	Female	.66 ±.194	1.05 ±.420	1.27 ±.33	1.51 ±.55	1.20 ±.43	1.32 ±.38	1.12 ±.57
Genu Maximum Thickness /(mm)	Male	9.02 ±2.03	10.57 ±2.32	12.36 ±1.86	13.08 ±2.22	12.64 ±1.57	11.62 ±2.26	9.70 ±1.35
	Female	8.02 ±1.63	11.04 ±2.10	12.93 ±1.59	12.94 ±2.23	12.30 ±1.74	10.41 ±1.92	11.14 ±2.96
Trunk Maximum Thickness /(mm)	Male	4.62 ±1.45	5.15 ±1.32	6.58 ±1.14	6.85 ±1.04	6.88 ±.78	6.08 ±.79	4.98 ±.90
	Female	4.68 ±1.21	6.20 ±1.16	6.89 ±.81	6.79 ±.90	7.18 ±.91	5.91 ±.75	6.27 ±1.80
Splenium Maximum Thickness /(mm)	Male	7.70 ±1.57	9.36 ±2.65	11.00 ±2.08	11.43 ±1.79	11.97 ±2.13	11.30 ±1.97	9.46 ±1.54
	Female	8.58 ±1.51	10.58 ±2.47	11.50 ±1.33	10.78 ±1.93	11.87 1.41	11.35 ±1.59	10.42 ±1.90

Fronto-Corpus Callosum Length /(mm)	Male	39.04 ±3.61	38.90 ±3.17	37.37 ±3.91	36.16 ±3.01	37.00 ±3.26	39.98 ±6.88	36.09 ±3.73
	Female	37.80 ±3.34	36.05 ±3.65	35.30 ±2.42	32.89 ±7.68	35.65 ±2.91	34.66 ±3.46	35.14 ±1.67
Occipito-Corpus Callosum Length /(mm)	Male	54.89 ±7.01	59.80 ±5.99	59.06 ±5.07	58.69 ±5.35	53.58 ±4.80	54.45 ±6.18	55.88 ±5.77
	Female	57.60 ±4.33	55.12 ±5.08	54.61 ±4.53	55.64 ±3.39	55.39 ±5.24	53.44 ±4.27	54.71 ±4.38
Corpus Callosum Index	Male	0.34 ±.05	0.35 ±.05	0.39 ±.044	0.40 ±.05	0.40 ±.04	0.37 ±.04	0.32 ±.05
	Female	0.35 ±.04	0.37 ±.09	0.41 ±.03	0.39 ±.03	0.39 ±.09	0.36 ±.03	.35 ±.06

Table 4.5: Dimensions of brain and corpus callosum compartments in Sudanese population classified according to gender with independent samples test.

Group Statistics					**Independent Samples Test**	
					Means	
Morphometric index	**Gender**	N	Mean	STDV	t	Sig. (2-tailed)
Fronto Occipital Length	Male	126	166.65	13.23	2.38	.018
	Female	107	163.11	8.43		
CC anteroposterior diameter	Male	126	75.15	11.36	.67	.499
	Female	107	74.31	6.56		
Rostrum Maximum Thickness	Male	125	1.27	.54	.82	.410
	Female	107	1.21	.46		
Genu Maximum Thickness	Male	126	11.33	2.45	-1.59	.112
	Female	107	11.83	2.30		
Trunk Maximum Thickness	Male	126	5.91	1.41	-3.77	.000
	Female	107	6.56	1.16		
Splenium Maximum Thickness	Male	126	10.31	2.34	-2.57	.011
	Female	107	11.04	1.92		
Fronto-Corpus Callosum Length	Male	126	37.31	3.88	3.99	.000
	Female	107	35.16	4.31		
Occipito-Corpus Callosum Length	Male	126	56.71	5.98	2.25	.025
	Female	107	55.12	4.55		
Corpus Callosum Index	Male	126	.37	.05	-2.17	.031
	Female	107	.38	.06		

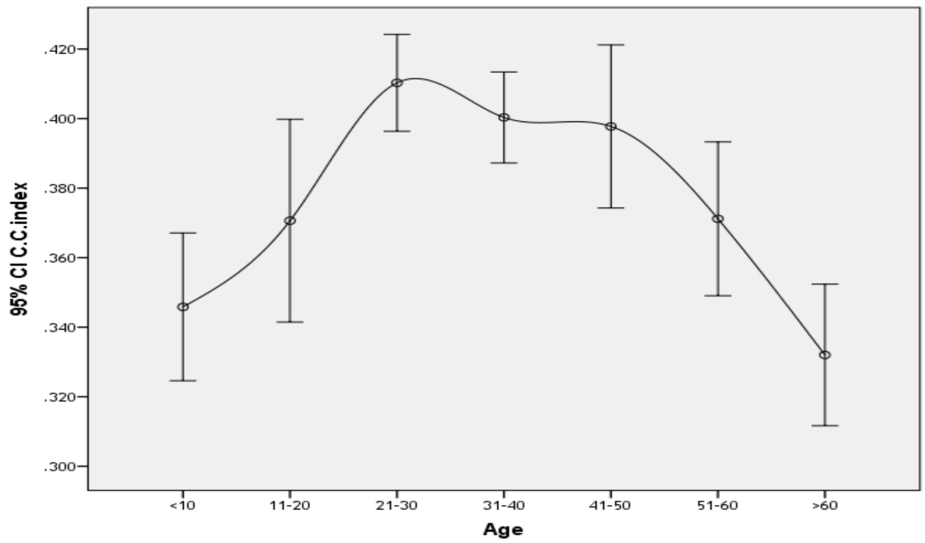


Figure 4.1 The maturation of corpus callosum considering the index and age classes during life development.

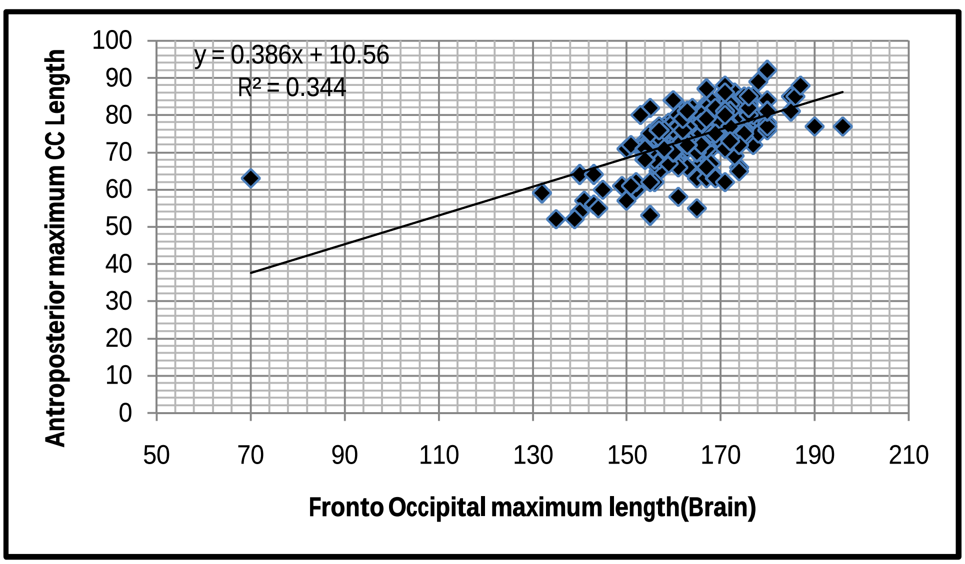


Figure 4.2 A scatter plot diagramme shows the linear relationship between the fronto occipital maximum length and CC maximum AP diameter. As the FOML increases the CCMAPD

increase by 0.39 mm starting from 10.56 mm {the contribution of the FOML to do change in the CC measurement is 34%} ,{regression equation y=0.386x+10.56}

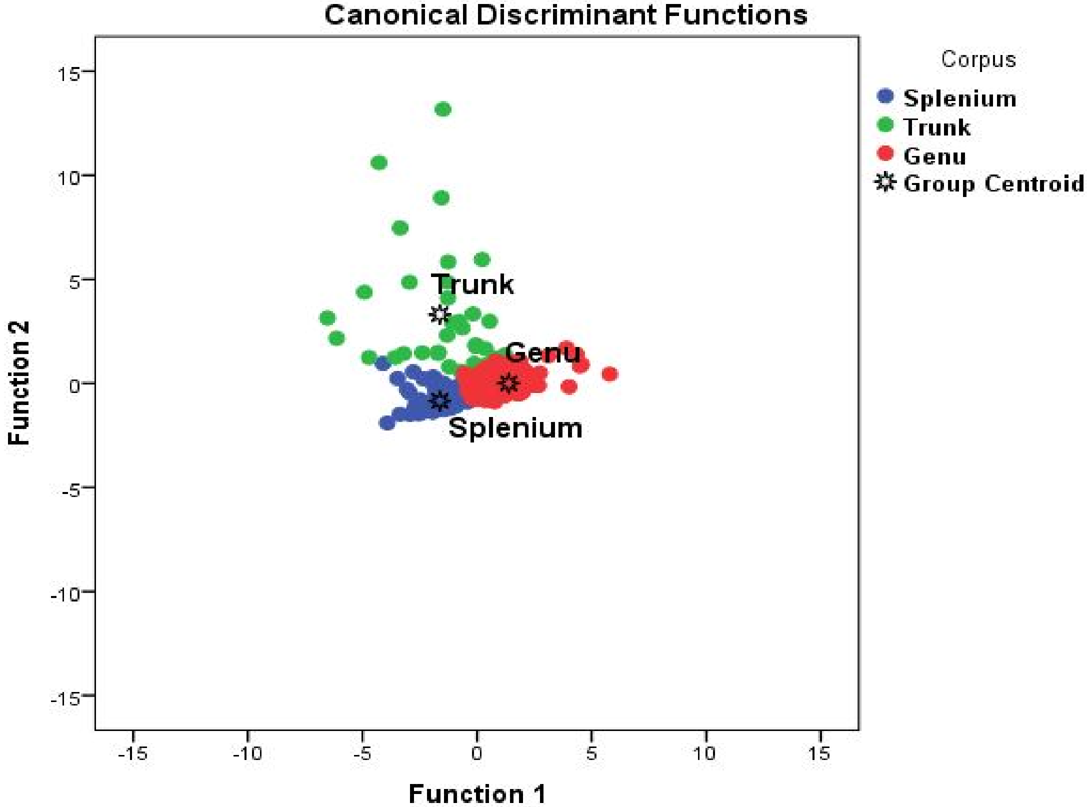


Figure 4.3 Scatter plot generated using discriminate analysis function for three classes ofcorpus collosum: splenium, trunk and genu .

the classification showed that the corpus collosum areas were classified well from the rest of the tissues although it has characteristics mostly similar to surrounding tissue.

Table 4.6 Showed the classification accuracy of the corpus collosum regions using lineardiscriminant analysis:

Corpus callosum		Predicted Group Membership			Total
		Splenium	Trunk	Genu	
%	Splenium	**100.0**	0.0	0.0	100.0
	Trunk	5.9	**76.5**	17.6	100.0
	Genu	3.0	0.0	**97.0**	100.0

a. 96.2% of original grouped cases correctly classified.

Table 4.6 show classification score matrix generated by linear discriminate analysis and the overall classification accuracy of corpus collosum parts 96.2%, were the classification accuracy of Splenium100.0 %, Trunk accuracy 76.5 %, While the Genu showed a classification accuracy 97.0%

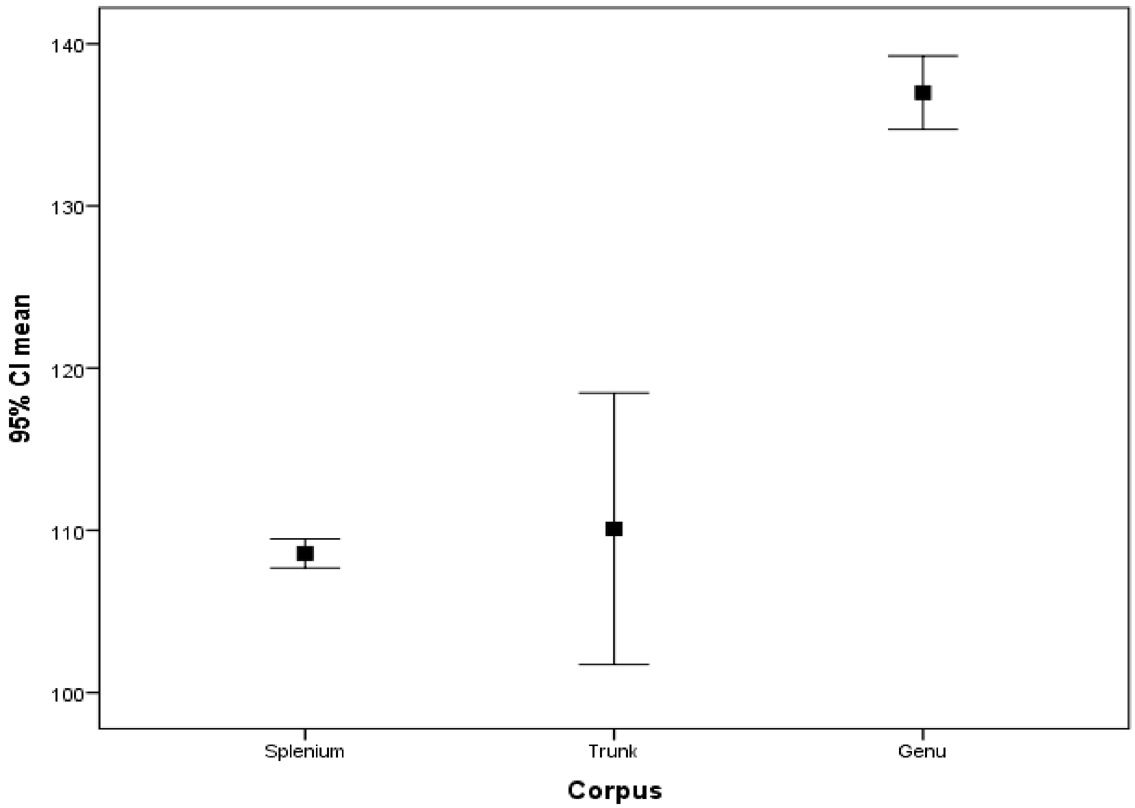


Figure 4.4 show error bar plot for the CI mean textural features that selected by the linear stepwise discriminate function as a discriminate feature where it discriminates between all features. From the discriminate power point of view in respect to the applied features the mean can differentiate between all the classes successfully.

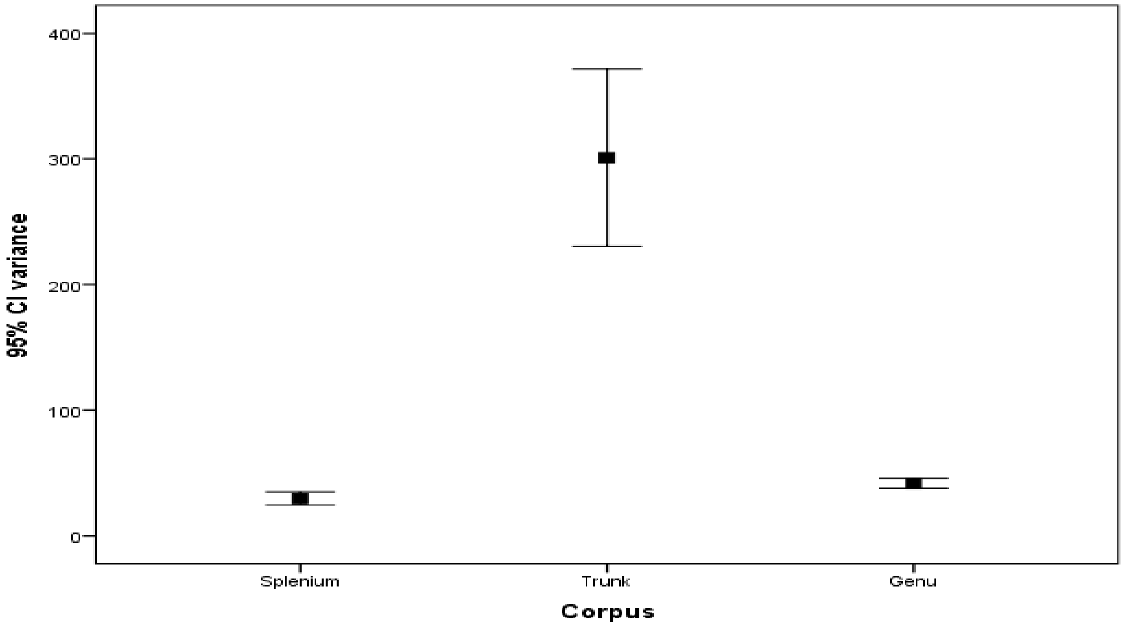


Figure 4.5 show error bar plot for the CI variance textural features that selected by the linear stepwise discriminate function where it discriminates between all features.

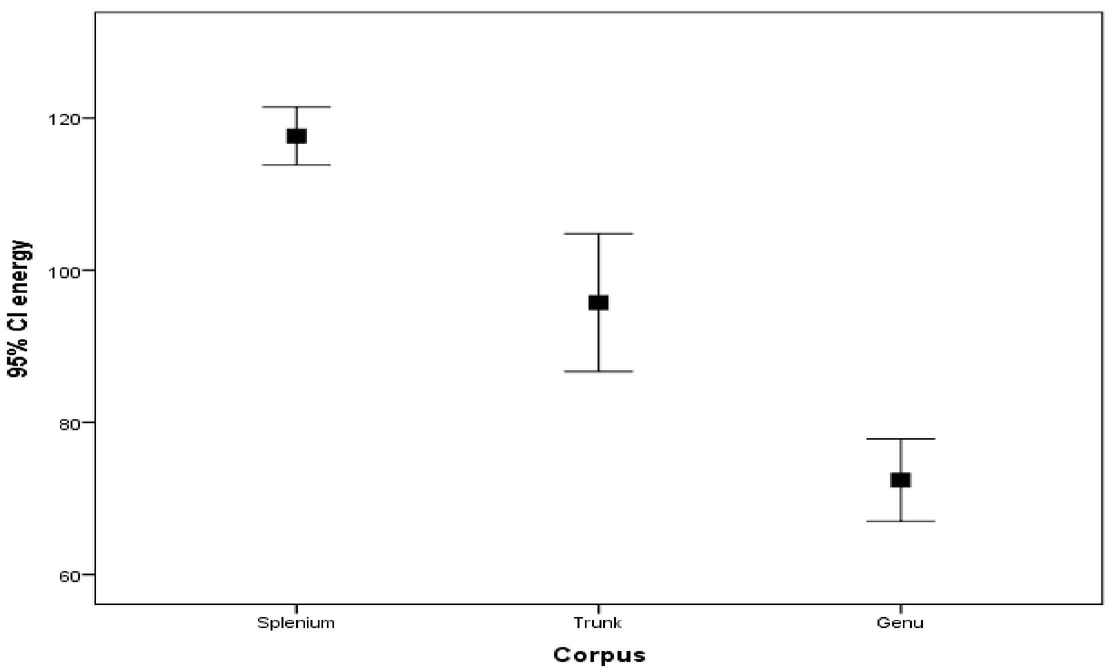


Figure 4.6 show error bar plot for the CI energy textural features that selected by the linear stepwise discriminate function where it discriminates between all features.

Chapter Five

Discussion, Conclusion and Recommendations

5.1 Discussion:

The (CC) is the major commissure connecting the cerebral hemispheres and there is evidence of its continuing development into young adulthood (Pujol et al.1993). However, few are known about changes in the characteristics of the CC compartments. Table (4.1) shows the measurements of the brain and the CC compartments for Sudanese measured in (mm). CC greatest anteroposterior diameter to Fronto occipital length (Ratio) was 0.45, that means it is around half of the brain measurement, the relation between them can be justified as that the segments of the CC (genu, body, rostrum and splenium) are topographically organized to carry interhemispheric fibers representing brain cortex and the development of each of these regions can provide approaching into the brain development (Matcheri et al.2002)The anatomical relation between the CC and brain is that CC is the main fiber tract connecting the two cerebral hemispheres (Eileen et al.2010). These data reflect the fact that the fronto callosal maximum distance and corpus callosum maximum antero posterior diameter (CCMAPD) have an association, as seen in figure (4.2) that shows the linear relationship between the two variables. As the fronto occipital maximum length (FOML) increases the CCMAPD increase by 0.39 mm starting from its measurement of 10.56 mm, the contribution of the FOML to do change in the CC measurement is 34%. Regarding the relation between the brain and CC dimensions in our study, we concluded that there is symmetry between the brain and the measurement of CC. This result is similar to (Estruch et al. 1997). and Mourgela et al.'s study (Mourgela et al.2007) and another Iranian study (Mohammadi et al. 2011) . Regression equation has been established for Sudanese CC: y=0.386 x+10.56; Corpus callosum maximum AP diameter (mm) = 0.386 X Frontocorpus maximum diameter (mm) +10.56.

The current study studied the age-related changes in the measurements of the brain and maximum thickness of the four compartments of the CC in the MRI scans of 233 healthy Sudanese individuals aged <10> 60 years. The impact of age has been studied comprehensively as noticed in table (4.2) and (4.3).

Fronto Occipital Length was found to be as maximum value at the age between 31-40 years with significant relation with the age except for occipital callosal length where no significant relation between this part and advancing age p=0.126. Total midsagittal measurements of the corpus callosum for all its compartments increased significantly across the age span although significant increases were limited to occipito-corpus callosum length. Fronto-CC maximum value was found in the age <10 and measured 38.78mm. CCAPD/(mm)reached its maximum at the age of 41-50 (79.77mm) ,RML at 31-40(1.52mm), GML at 31-40(13.03mm) ,BML at 41-50(7.05mm),SML at 41-50(11.92mm) and CCI maximum maturation value at the age between21-30(0.41).

Table (4.4) presented morphometric index/ chart established for brain and CC dimensions in Sudanese population for both genders at similar age classes.

In current study without considering the gender, according to age group we observed development of CC continued and showed statistical significant relationship between the age and its compartments at (p< 0.05).The significant relation between the fronto occipital diameter of brain with age and the maturation of the genue is that they are correlated to each other’s where the genu region is linked with the prefrontal cortex (Keshavan et al.2002). A similar view by Luders et al was given ,they stated that genue growth may start in late adolescent period when frontal lobe is actively developed (Luders et al.2010) , that is where the maximum value for the genue was found at the ages between 31-70years in our study. Keshavan et al, has reported that between children and adolescent and between adolescent and young adults, the genu region is significantly increasing (Keshavan et al. 2002). However, in their study, the distribution of age groups is obviously doesn’t match with the age group in our recent study.

The gender has an impact on the changes detected in the brain and CC compartments except for the rostrum, genu, callosal AP maximum diameter. In a study done in Iranian population(Mohammadi et al. 2011), there was no significant difference detected in CC diameters between genders. and they were similar to the findings of Takeda’s study in Japan (Takeda et al.2003),and Tuncer’s study in Turkey (Tuncer et al.2005). The current study showed that there is significant difference between the splenium in both genders as noticed in table(5).This findings was of reverse results to studies of human CC, who mentioned the insufficient evidence to support the presence of sex related differences in the size or shape of the splenium (Bishop et al.1997) , other study showed no gender related difference of splenium in the Japanese (Takeda et al. 2003) ,and in the Indians (Banka et al.2003 ; Suganthy et al. 2003).

Another study showed no significant difference in splenial width found between males and females(Gupta et al.2009). Another study found a significant gender related differences in the thickness of splenium (Mohammadi et al. 2011) .

However, on the basis of our findings in the present study, one can conclude that Sudanese differs from other population and there is significant sexual dimorphism in splenium. The differences on quantitative data of CC in various areas of the world which were seen in different studies may be due to racial/ethnic factors (Takeda et al. 2003, Gupta et al.2009).

Brain dimensions were significantly larger in males than in females (P < 0.05),and reverse findings were found in the CC trunk maximum thickness, splenium maximum thickness and CCI where females were greater than males with significant difference at 0.000,0.011 and 0.031 respectively as noticed in table (4.5), similar results was mentioned by (De-Lacoste and Holloway 1982). Some studies have reported greater width of trunk in females (Witelson 1989; Clarke and Zaidel 1994). These findings were observed in current study .Another studies showed larger genu in males (Witelson 1989; Banka and Jit 1996). [and a larger anterior trunk in males (Witelson ,1989). Most studies have failed to find any evidence of sexual dimorphism in CC. Some studies have reported greater splenial width and area in females (Allen et al.1991; Davatzikos et al.1998). Bishop and Wahlstein (Bishop KM et al.1997).

Witelson (1989) also did not report any gender related differences in splenial areas. Similarly, an Indian study (Banka and Jit 1996) . also failed to find gender related difference in splenium. Our results concerning Sudanese were not in agreement with most of the literature. The maturation of the CC has been described to begin at approximately 8 to 10 weeks of gestation (Barkovich & Kjos 1988) ; Barkovich & Norman 1988). Number of collosal fibers are fixed at birth, however, structural changes at CC continues due to myelinination of fibers during postnatal development, redirection, pruning and myelination (Barkovich & Norman 1988) .The complete formation of CC continues to enlarge throughout infancy, childhood, and young adulthood (Dubovsky et al.2001). Schaefer et al stated that growing of CC continues till the 15 year age and during this period it could be reflections of increasing the myelinisation of CC (Schaefer et al.1990).On the other hand Simon et al claimed growing of CC continues until the 18th year-old (Simon et al.1987) .In our study without considering the gender and according to age group we observed maturation of CC continued and showed significant increasing with age with maximum values for CCI were found at the ages between the 21-30 age and measured 0.41.One study done by Mehmet Ilkay Kosar 2012 (Mehmet et al.2012). shows that the CCI was 0.44 ± 0.05 at the age 6-9 years, 0.46 ± 0.05 at 10-13 years and 0.45 ± 0.03 at the age 14-17 years old.

In current study CCI showed significant difference between the two genders at p=0.031 ,CCI in males was 0.37 and in females was 0.38 ,it increased by increasing age and then it reduced thereafter figure(4.1) and table(4.5). Total midsagittal CCI (Splenum, body, Genu ,rostrum and CC maximunm AP length) increased strongly across this age span for both genders, although significant increases were limited for corpus to occipital brain regions. The maturation of brain and CC compartments across the age less than 10 and greater than 60 was presented in table (4.4) for both genders. It was considered as chart for Sudanese norms for development .The majority of maturational changes in the splenium of the CC across this age span suggests the anterior sections may have already reached their adult sizes in the childhood age 11-20 was (9.36±2.65) for males and(10.58±2.47) for females which is similar to the measures found at the age more than 60. This possibility was investigated by comparing our pediatric data to scans on adults subjects aged 20-60, acquired and analyzed in an identical approach, as noticed in table (4.4)

There were little differences between the adolescent and adult means in the rostrum; in the childhood ages between 11-20 and ages more than 60 for both genders as well the changes appears in the genu at the age group less than 10 years was found to be small for both males and females comparing to the subjects whose age greater than 60 years old. This is in contrast to the remaining mid and posterior part which was significantly smaller for the pediatric group. This supports the concept that the rostrum and genu plateau at adult sizes early in development (Jay et al1996).

Ongoing development of the body/trunk of the CC is consistent with continued maturation of higher association well into adulthood, since a large amount of callosal fibers derived from these parts (Pandya et al.1985).

However aging affected this maturation, to be decreased by increasing age for both genders significantly. We had detected changes in the genue and restrum regions in both genders, the changes was found to be due to age but not statistically correlated with gender. Perhaps the increasing frontal connectivity patterns of adolescence involve mainly intra hemispheric, as opposed to inter hemispheric, structures. This anterior-to-posterior CC maturation, reflects anterior/posterior patterns of inter hemispheric myelination and connectivity during normal development (Jay et al.1996).

Characterize the corpus collosum parts to splenium, trunk and genu in MR images using first order statistic and extract classification features from MR images. The FOS techniques included eight's features, and carried out using Interactive Data Language (IDL).The result of the classification showed that the corpus collosum areas were classified well from the rest of the tissues.

Using first order statistic the features give a classification accuracy of corpus collosum parts for splenium 100.0%, trunk 76.% and the genu classification accuracy 97.0%. The overall classification accuracy of corpus collosum area 96.2% as noticed in table 4.6 .As well using linear discriminal analysis step wise method three features has been selected from seven features to form linear discriminal equations, where the vote will be attributed to highest valu to discriminate between genu, trunk and splenium as follow:

Splenium = (mean×0.513) + (variance × 0.009) + (energy × 0.022) – 30.397

Trunk= (mean × 0.558) + (variance × 0.07) + (energy × -0.012) – 41.76

Genu = (mean × 0.725) + (variance × 0.014) + energy × -0.058) – 48.94 .

5.2 .1 Conclusion

All dimensions of CC compartments and brain have significant relation with increasing age at p=0.000 except for occipito-corpus callosum length where no significant relation was detected (p=0.126). The gender has an impact on the changes detected in the brain and CC compartments except for the rostrum, genu, callosal AP maximum diameter. Brain dimensions were significantly larger in males than in females at ($P \leq 0.05$). Reverse findings were found in the CC trunk, splenium maximum thickness and CCI, where females were greater than males with significant difference at P= 0.000, 0.011 and 0.031 respectively. The CCI increased with age and then decreased thereafter. There was also a positive linear relationship between the AP length of the CC and the fronto-corpus callosum length. Regression equation for predicting the length of the CC and morphometric index of CC in the Sudanese population in both genders at similar age classes has been established (y=0.386×+10.56 R^2 =0.344. A local reference for normative data of Sudanese brain and CC morphometric indices has been established during maturation for both genders.

from Linear discrimination analysis generated a classification function which can be used to classify other image into the mention classes as using the following multi regression equation:

Splenium = (mean×0.513) + (variance × 0.009) + (energy × 0.022) – 30.397

Trunk= (mean × 0.558) + (variance × 0.07) + (energy × -0.012) – 41.76

Genu = (mean × 0.725) + (variance × 0.014) + energy × -0.058) – 48.94 .

5.3 Recommendations:

- The study recommended to use MRI T1 weighted images in characterization of corpus callosum combined with texture analysis program with increasing the sample size.
- The study recommended further study about the use of US to measure corpus callosum in neonates to standardize a normal reference of measurement for Sudanese.
- The study recommended to use US for characterizing the corpus callosum in Sudanese infants population to be as stander reference value at that age . as the young ages did not included in current study .
- Further studies of the corpus callosum measurement in different tribes
- in Sudan using MRI measurements is recommended under the effect of race/ ethnicity.

References:

Allen LS, Richey MF, Chai YM, Gorski RA. Sex differences in the corpus callosum of the living human being. J Neurosci1991; 11: 933-42.

Arkovich AJ. (1996). Analyzing the corpus cal-losum. AJNR Am J Neuroradiol; 17:1643–1645.

Aydlnlioglu A, Diyarbakirli S, Yuceer N, Keles P, Nnal O, Erdogan A R (1996) The relationship of sex differences to the anatomy of corpus callosum in the living human being 6: 1 – 4.

Banka S, Jit I. 1996Sexual dimorphism in the size of the corpus callosum. J Anat Soc of India; 45: 77-85.

Barkovich JA, Kjos BO. 1988Normal postnatal development of the corpus callosum as demonstrated by MR imaging. Am J Neuroradiol;9:487-491.

Barkovich JA, Norman D. 1988Anomalies of the corpus callosum: correlation with further anomalies of the brain. Am J Roentgenol.;51:171-179.

Bearden, C. E., Van Erp, T. G. M., Dutton, R.A., Boyle, C., Madsen, S., Luders, E., Kieseppa, T., Tuulio-Henriksson, A., Huttunen, M., and Partonen, T. (2011). Mapping cor-pus callosum morphology in twin Pairs discordant for bipolar disor-der. Cereb. Cortex 21, 2415–2424.

Bearden, C.E., Van Erp, T. G. M., Dutton, R. A., Boyle, C., Madsen, S., Luders, E., Kieseppa, T., Tuulio- Henriksson, A., Huttunen, M., and Partonen,T.(2011). Mapping cor- pus callosum morphology in twin Pairs discordant for bipolar disorder. Cereb.Cortex 21, 2415–2424.

Bellis TJ, Wilber LA. Effects of aging and gender on interhemispheric function. J Speech Lang Hear Res 2001;44: 246-63.

Bermudez P, Zatorre RJ. 2001Sexual dimorphism in the corpus callosum: methodological considerations in MRI morphometry. Neuroimage.;13(6 Pt1):1121-30.

Bishop KM, Wahlstein D (1997): Sex differences in the human corpus callosum: myth or reality? Neurosci Biobehav Rev 1997; 21: 581-601.

Catherine Westbrook (2008), Handbook of MRI technique, Blackwell Publishing Ltd, 3rd Ed.

Catherine Westbrook (2008), Handbook of MRI technique, Blackwell Publishing Ltd, 3rd Ed.

Clarke JM, Zaidel E. 1994Anatomical–behavioral relationships: corpus callosum morphometry and hemispheric specialization. Behav Brain Res; 64: 185-202.

Davatzikos C, Resnick SM. 1998Sex difference in anatomic measures of interhemispheric connectivity: Correlations with cognition in women but not men. Cereb Cortex; 8: 635-40.

De Lacoste-Utamsing, C., and Holloway, R. L. 1982. Sexual dimorphism in the human corpus callosum. Science 216: 1431–1432.

Di Paola, M., Luders, E., Cherubini, A., Sanchez-Castaneda, C., Thompson,P. M., Toga, A. W., Caltagirone, C., Orobello, S., Elifani, F., and Squitieri, F. (2012). Multimodal MRI analysis of the corpus cal-losum reveals white matter dif-ferences in presymptomatic andearly Huntington’s disease. Cereb.Cortex. doi:10.1093/cercor/bhr360.[Epub ahead of print].

Di Paola, M., Spalletta, G., and Caltagirone, C. (2010). In vivostructural neuroanatomy of corpus callosum in Alzheimer’s disease and mild cognitive impairment usingdifferent MRI techniques: a review.J. Alzheimers Dis. 20, 67–95.

Dubovsky EC, Booth TN, Vezina G, Samango-SprouseCA, Palmer KM, Brasseux CO. 2001MR imaging of the corpus callosum in pediatric patients with neurofibromatosis type1. Am J Neuroradiol.;22(1):190-195.

Eileen Luders, Paul M. Thompson, Arthur W. Toga 2010 The Development of the Corpus Callosum in the HealthyHuman Brain The Journal of Neuroscience, 30(33):10985–10990 10985.

Elster AD, Dipersio DA, Moody DM (1990) Sexual dimorphism of the human corpus callosum studied by magnetic resonanceimaging: fact, fallacy and statistical confidence. Brain Dev; 12: 321-5.

Estruch R, Nicolas JM, Salamero M, Aragon C, Sacanella E, Fernandez-Sola J, et al. 1997Atrophy of the corpus callosum in chronic alcoholism. J Neurol Sci.;146(2):145-51.

Frederiksen, K. S., Garde, ESkimminge, A., Ryberg, CRostrup, E., Baaré, W., Siebner H., Hejl, A. M., Leffers, A.M., and Waldemar, G. (2011b). Corpus callosum atrophy in patients with mildAlzheimer’s disease. NeurodegenerDis. 8, 476–482.

Giedd JN, Rumsey JM, Castellanos FX , Rajapakse JC, Kaysen D, Vaituzis AC, Vauss YC, Hamburger SD, Rapoport JL (1996) A quantitative MRI study of the corpus callosum in children and adolescents 9:274-280.

Gilliam, M., Stockman, M., Malek,M., Sharp, W., Greenstein, D.,Lalonde, F., Clasen, L., Giedd, J.,Rapoport, J., and Shaw, P. (2011).Developmental trajectories of thecorpus callosum in attention-deficit/hyperactivity disorder. Biol.Psychiatry 69, 839–846.

Gupta E, Khan A, Babu CR, Lalwani R, Aneja S (2011) Sexual dimorphism of splenial thickness of corpus callosum 2 (1): 63-66.

Gupta T, Singh B, Kapoor K, Gupta M and Kochhar S (2008) Age and sex related variations in Corpus Callosal morphology; 10(4): 215-221.

Gupta T, Singh B, Kapoor K, Gupta M, Kochhar S.. 2009Normative Data of Corpus Callosal Morphology in a North-West Indian Population- An autopsy and MRI study. J Nepal Med Assoc; 48: 46-51.

Gurd, J. M., Cowell, P.E., Lux, S., Rezai, R., Cherkas, L., and Ebers, G.C. (2012). fMRI and corpus callosum relationships in monozygotic twins discordant for handedness. Brain Struct. Funct. doi:10.1007/s00429- 012-0410-9.

Hallak et al. (2007) Total Agenesis of the Corpus Callosum in a Patient with Childhood-Onset Schizophrenia, Arq Neuropsiquiatr; 65(4-B):1216-1219.

Hasan, K. M., Molfese, D. L., Walimuni, I. S., Stuebing, K. K., Papanicolaou, A. C., Narayana, P. A., and Fletcher, J. M. (2012a). Diffusion tensor quantification and cognitive cor-relates of the macrostructure and microstructure of the corpus cal-losum in typically developing and dyslexic children.NMR Biomed. doi:10.1002/nbm.2797. [Epub ahead ofprint].

Hasan, K. M., Walimuni, I. S., Abid,H.,Wolinsky,J.S.,andNarayana,P.A. (2012b). Multi-modal quantita-tive MRI investigation of brain tis-sue neurodegeneration in multiplesclerosis. J.Magn.Reson.Imaging.35, 1300–1311.

Heilman KM, Valenstein EBogen JE*(1979) in Clinical neuropsychology, The callosal syndromes, eds Heilman KM, Valenstein E (Oxford UP, New York), pp 308–359.*

Herlidou-Même S et al (2003) MRI texture analysis on texture test objects, normal brain and intracranial tumors. Magnetic Resonance Imaging, 21(9):989-93.

Jay N. Giedd, Judith M. Rumsey, F. Xavier Castellanos, Jagath C. Rajapakse, Debra Kaysen,A. Catherine Vaituzis, Yolanda C. Vauss, Susan D. Hamburger, Judith L. Rapoport 1996 A quantitative MRI study of the corpus callosum in children and adolescents, Developmental Brain Research Volume 91, Issue 2, , Pages 274-280.

Keshavan MS, Diwadkar VA, DeBellis M, Dick E, Kotwal R,Rosenberg DR, et al. 2002Development of the corpus callosum in childhood, adolescence and early adulthood. Life Sci.;70(16):1909-1922.

Kovalev VA, Kruggel F, Gertz HJ, von Cramon Y: Three dimensional texture analysis of MRI brain datasets. IEEE Trans Med Imaging. 2001, 20: 424-433. 10.1109/42.925295.

Laissy JP, Patrux B, Duchateau C, Hannequin D, Hugonet P, Yahia HA, Thiebot J (1993) Midsagittal MR Measurements of the Corpus Callosum in Healthy Subjects and Diseased Patients. 14(2): 145- 154.

Luders E, Rex DE, Narr KL, Woods RP, Jancke L, Thompson PM,et al. 2003Relationships between sulcal asymmetries and corpus callosum size: gender and handedness effects. Cereb Cortex.;13(10):1084-93.

Luders E, Thompson PM, Toga AW. 2010The development of the corpus callosum in the healthy human brain. J Neurosci.;18;30(33):10985-10990.

Luders, E., Di Paola, M., Tomaiuolo,F., Thompson, P. M., Toga, A.W., Vicari, S., Petrides, M., andCaltagirone, C. (2007a). Callosalmorphology in Williams syndrome: a new evaluation of shape and thick-ness. Neuroreport 18, 203.

Luders, E., Narr, K. L., Hamilton, L.S., Phillips, O. R., Thompson, P.M.,Valle,J.S.,Del'homme,M.,Strickland, T., Mccracken, J. T.,and Toga, A. W. (2009). Decreasedcallosal thickness in attention-deficit/hyperactivity disorder. Biol.Psychiatry 65, 84–88.

M.R.E Dean (1990) Basic Anatomy and Physiology for Radiographers, F.A. Davis Co., 1st Ed.

Maller, J. J., Thomson, R. H., Lewis, P.M., Rose, S.E., Pannek, K., and Fitzgerald, P. B. (2010). Traumatic brain injury, major depression, and diffusion tensor imaging: making connections. Brain Res. Rev. 64,213–240.

Matcheri S. Keshavan, Vaibhav A. Diwadkar, Michael DeBellis,Elizabeth Dick, Rupali Kotwal, David R. Rosenberg, John A. Sweeney,Nancy Minshew, Jay W. Pettegrew (2002) Development of the corpus callosum in childhood,adolescence and early adulthood Life Sciences 70 1909–1922.

Mitchell T N, Free S L, Merschhemke M, Lemieux L, Sisodiya S M, and Shorvon S D (2003) Reliable Callosal Measurement: PopulationNormative Data ConfirmSex-Related Differences 24:410–418.

Mohammad Reza Mohammadi, Pouya Zhand, Behnoush Mortazavi Moghadam, Mohammad Jafar Golalipour. Iran 2011Measurement of the Corpus Callosum Using Magnetic Resonance Imaging in the North of Iran J Radiol.;8(4):218-223. DOI: 10.5812/iranjradiol.4495.

Mohammadi MR, Zhand P Moghadam BM, Golalipour MJ (2011) Measurement of the corpus callosum using magnetic resonance imaging n the north of iran. Iran J Radiol.8(4):218-223.

Mourgela S et al (2006) An MRI study of sex- and age-related differences in the dimensions of the corpus callosum and brain.Neuroanatomy6: 63–65.

Mourgela S, Anagnostopoulou S, Sakellaropoulos A, Gouliamos A. 2007An MRI study of sex-and age-related differences in the dimensions of the corpus callosum and brain. Neuroanatomy.;6(1):63-5.10-14.

Okamoto K, Ito J, Tokiguchi S. 1990 [The MR findings on the corpus callosum of normal young volunteers]. Nihon Igaku HoshasenGakkai Zasshi.;50(8):954-63.

Oliveira MS et al (2012)MRI-texture analysis of corpus callosum, thalamus, putamen, and caudate in Machado-Joseph disease.JNeuroimaging22(1):46-52.

Pandya, D.N. and Rosene, D.L., 1985Some observations on trajectories and topography of commissural fibers. In A.G. Reeves (Ed.), Epilepsy and the Corpus Callosum, Plenum, New York, , pp.21-35.

Parizel P M, Hauwe L, Belder F D, Goethem J V, Venstermans C, Salgado R, Voormolen M, and Hecke W V .(2010). Magnetic Resonance Imaging of the Brain 2, 107-194.

Paul, L. K .(2011). Developmental malformation of the corpus callosum: a review of typical callosal development and examples of developmental disorders with callosal involvement. J. Neurodev.Disord. 3, 3–27.

Peterson BS, Feineigle PA, Staib LH, Gore JC. 2001Automated measurement of latent morphological features in the human corpus callosum.Hum Brain Mapp.;12(4):232-45.

Pujol J, Vendrell P, Junque C, Marti-Vilalta JL, Capdevila A. 1993When does human brain development end? Evidence of corpus callosum growth up to adulthood. Annals of Neurology;34:71–5.

Reinarz SJ, Coffman CE, Smoker WRK, Godersky JC. 1988MR imaging of corpus callosum: Normal and pathologic findings and correlationwith CT. AJNR; 9: 649-56.

Sampaio, A., Bouix, S., Sousa, N.,Vasconcelos, C., Fernandez, M.,Shenton, M. E., and Goncalves, Ã.F. (2012). Morphometry of cor-pus callosumin Williams syndrome: shape as an index of neural devel-opment. Brain Struct. Funct. doi:10.1007/s00429-012-0423-4. [Epub ahead of print].

Schaefer GB, Thompson JN, Bodensteiner JB. 1990Quantitative morphometric analysis of brain growth using magnetic resonance imaging. J Child Neurol.;5:127-130.

Simon JH, Schiffer RB, Rudick RA, Herndon RM. 1987Quantitative determination of MS-induced corpus callosum atrophy in vivo using MR imaging. Am J Neuroradiol.;8:599-604.

Sperry, R. W. 1968. Hemisphere disconnection and unity in con-scious awareness. Am. Psychol. 23: 723–733.

Standring S. et al.(2005) Gray’s Anatomy: The Anatomical Basis of Clinical Practice (39ed). London Elsevier Churchill Livingstone 411-414.

Suganthy J, Raghuram L, Antonisamy B, Vettivel S, Madhavi C, Koshi R. 2003Gender and Age related differences in the morphology of the corpus callosum. Clin Anat; 16: 396-403.

Sukkar M. Y, H. A. Elmunshid and M. S. M. Ardawi. (2000). Consice Human Physiology, 2nd. Edition, Blackwell Science, Paris-France.

Sun, J., Maller,J., Daskalakis, Z., Furtado, C., and Fitzgerald, P.(2009). Morphology of the corpus callosum in treatment resistantschizophrenia and major depres-sion. Acta Psychiatr. Scand. 120, 265–273.

Takeda S, Hirashima Y, Ikeda H, Yamamoto H, Sugino M, Endo S. 2003Determination of indices of the corpus callosum associated with normal aging in Japanese individuals. Neuroradiology.;45(8):513-8.

Tepest, R., Jacobi, E., Gawronski, A., Krug, B., Möller-Hartmann, W., Lehnhardt, F. G., and Vogeley,K. (2010). Corpus callosum sizein adults with high-functioningautism and the relevance of gender. Psychiatry Res. 183, 38–43.

Timothy J. Herron, Xiaojian Kang and David L.Woods 2012Automated measurement of the human corpus callosum using MRI Frontiers in Neuro informatics www.frontiersin.org September |Volume6|Article25 | 1-15.

Tomaiuolo, F., Scapin, M., DiPaola, M., Le Nezet, P., Fadda, L., Musicco, M., Caltagirone, C., and Collins, D.(2007). Gross anatomy of the cor-pus callosum in Alzheimer's dis-ease: regions of degeneration and their neuropsychological correlates. Dement. Geriatr. Cogn. Disord. 23,96–103.

Tuceryan, M. and Jain, A. K., The handbook of pattern recognition and computer vision,2nd ed. Singapore: World Scientific, 1998.

Tuncer MC, Hatipoglu ES, Ozates M. 2005Sexual dimorphism and handedness in the human corpus callosum based on magnetic resonance imaging. Surg Radiol Anat.;27(3): 254-9.

Vishram Singh (2004), Textbook of Clinical Neuroanatomy, ELSEVIER, 1st Ed.

Wahl M, Lauterbach-Soon B, Hattingen E, Jung P, Singer O, Volz S, Klein JC, Steinmetz H, Ziemann U*(2007) Human motor corpus callosum: topography, somatotopy, and link between microstructure and function. J Neurosci 27:12132–12138.*

Walterfang, M., Yücel, M., Barton, S., Reutens, D.C., Wood, A.G., Chen, J., Lorenzetti, V., Velakoulis, D., Pantelis, C., and Allen, N.B. (2009b). Corpus callosum size.

Witelson SF. 1989Hand and sex differences in the isthmus andgenu of the human corpus callosum. A postmortem morphological study. Brain; 112: 799-835.

Zaidel E, Iacoboni M, *eds (2003) The parallel brain: the cognitive neuroscience of the corpus callosum (MIT, Cambridge, MA).*

www.braintumoursurgery.co.uk/brain-anatomy/
www.sigrid.knemeyer.com/portfolio/mid-section-of-the-brain/
www.csuchico.edu/~pmccaffrey//syllabi/cmsd%20320/362unit11.html
https://www.pinterest.com/evanmariah/cross-sectional-anatomymrct/

www.studyblue.com/notes/note/n/25a-gross-brain-i/deck/13404661

http://hubel.med.harvard.edu/book/b34.htm

www.emedicine.medscape.com/article/407730-overveiu#1

http://emedicine.medscape.com/article/407730-overview

http://emedicine.medscape.com/article/407730-overview

http://emedicine.medscape.com/article/407730-overview

http://emedicine.medscape.com/article/407730-overview

http://casemed.case.edu/clerkships/neurology/Web%20Neurorad/MRI%20Basics.htm

http://bioengineering.rice.edu/Content.aspx?id=2147483699

Appendices

Appendix (A)

Data collection sheet

No	Gender	Age	AB (Fronto-occipital length)	EZ (Cospus Callosum Length)	Rostrum width	Genu width	Trunk width	Splenium width	AE (Fronto-corpus length)	ZB (occpito-corpus length)	CCI (Corpus callousm index)

Appendix (B)

(Images)

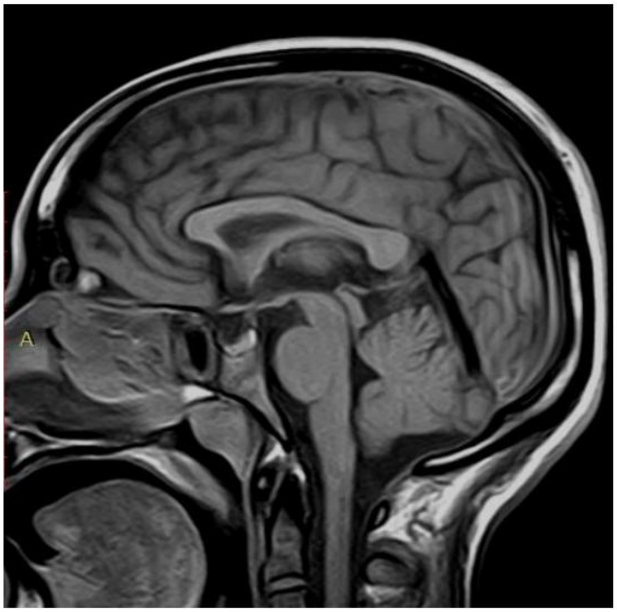


Image 5.1: Sagittal T1 for male patient (40 Y) (TR: 676.0, TE: 10.0, slice thickness: 5.0 mm).

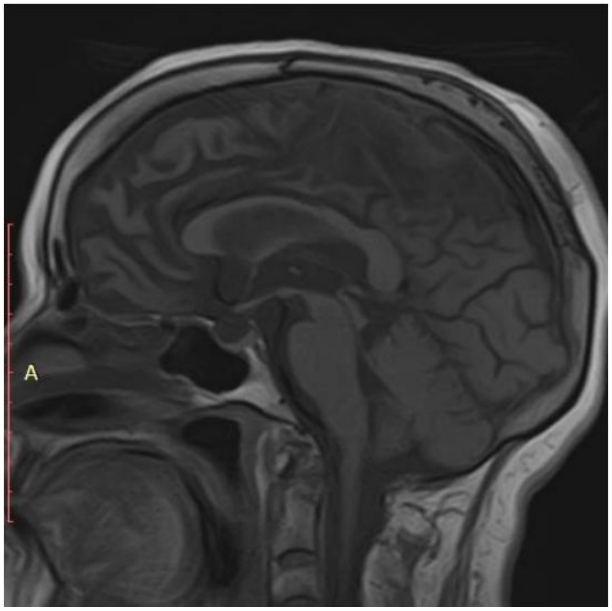


Image 5.2: Sagittal T1 for male patient (55 Y) (TR: 676.0, TE: 10.0, slice thickness: 5 (mm).

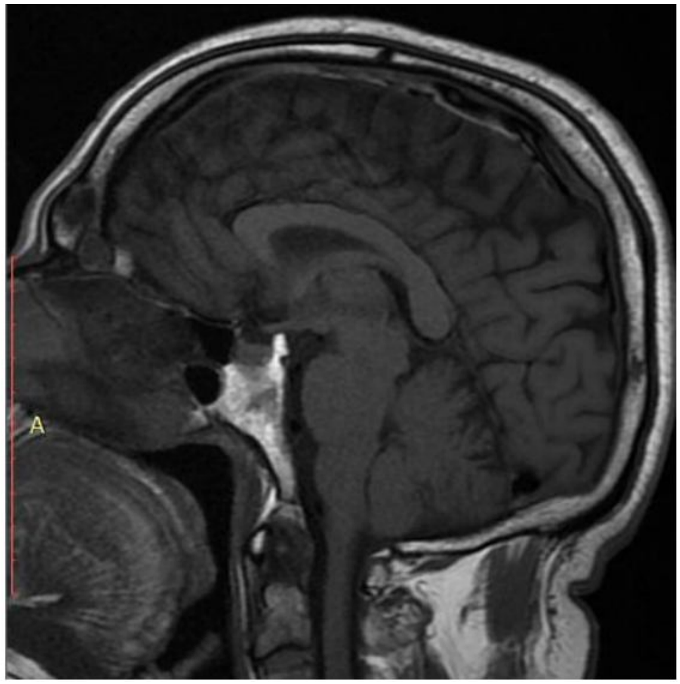


Image 5.3: Sagittal T1 for male patient (60 Y) (TR: 676.0, TE: 10.0, slice thickness: 5.0 mm).

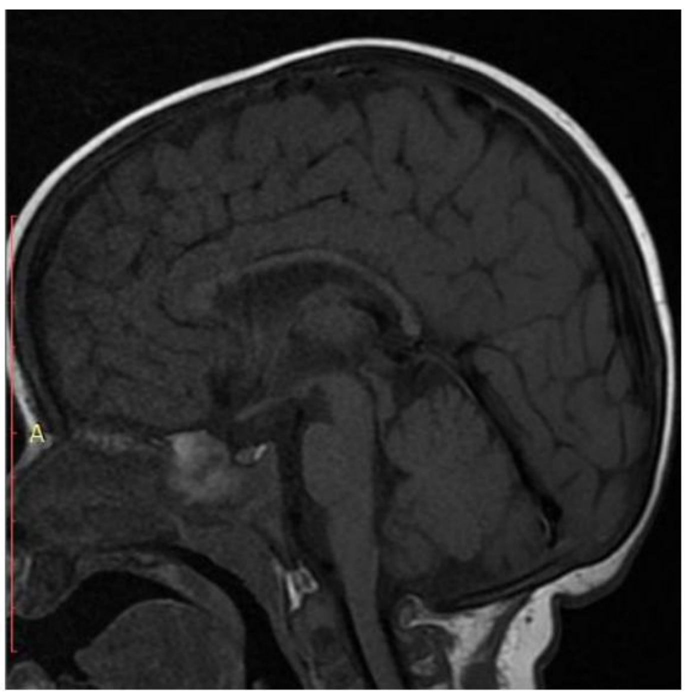


Image 5.4: Sagittal T1 for male patient (10 Y) (TR: 676.0, TE: 10.0, slice thickness: 5.0 mm).

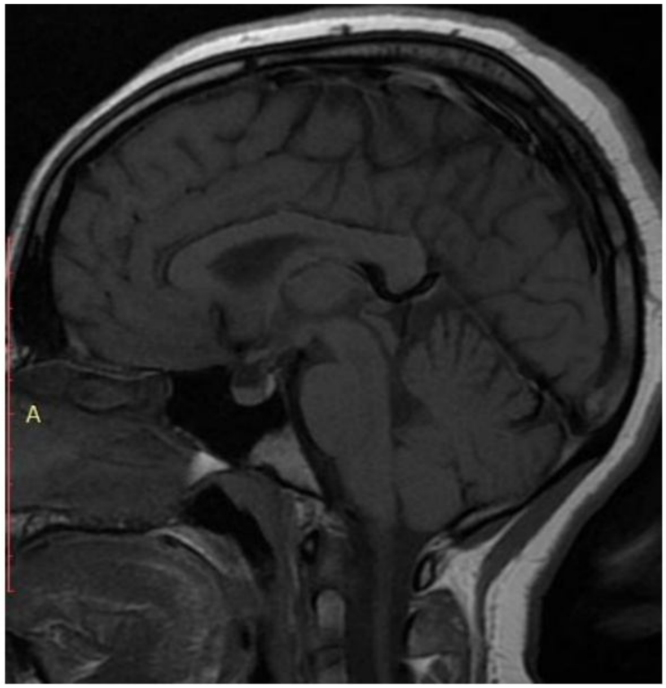


Image 5.5: Sagittal T1 for female patient (23 Y) (TR: 676.0, TE: 10.0, slice thickness: 5.0 mm).

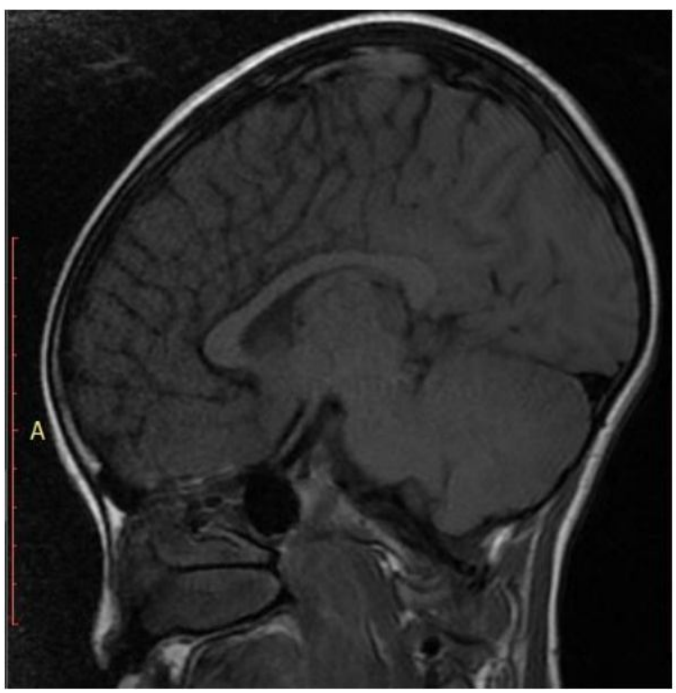


Image 5.6: Sagittal T1 for female patient (12 Y) (TR: 676.0, TE: 10.0, slice thickness: 5.0 mm).

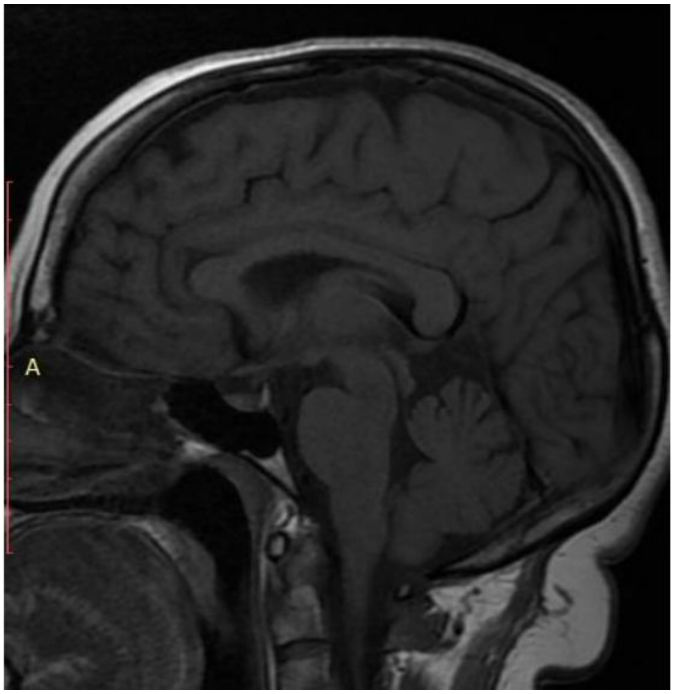


Image 5.7: Sagittal T1 for female patient (50Y) (TR: 676.0, TE: 10.0, slice thickness: 5.0 mm).

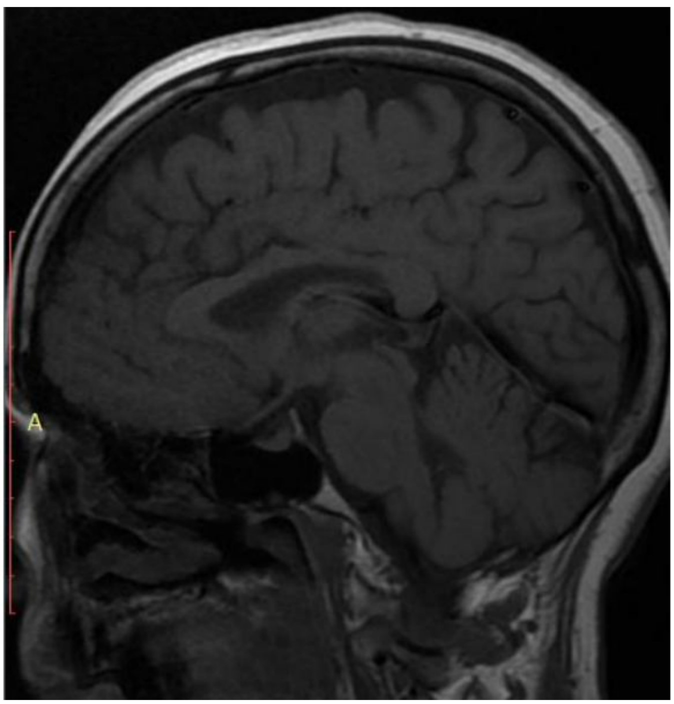


Image 5.8: Sagittal T1 for female patient (45Y) (TR: 676.0, TE: 10.0, slice thickness: 5.0 mm).

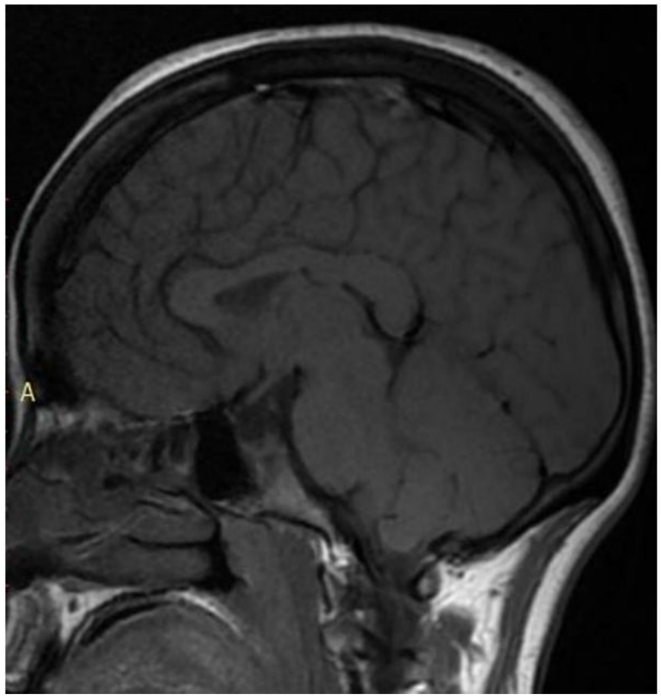


Image 5.9: Sagittal T1 for female patient (25Y) (TR: 676.0, TE: 10.0, slice thickness: 5.0 mm).

Accomplishment

IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)
e-ISSN: 2279-0853, p-ISSN: 2279-0861.Volume 16, Issue 7 Ver. III (July. 2017), PP 77-86
www.iosrjournals.org

A quantitative MRI study of the normative corpus callosum in Sudanese

Amna Mohamed Ahmed Ibrahim Mustafa[1], Mohamed Elfadil Mohammed Garelnabi[1], *Caroline Edward Ayad[1]
[1]*Sudan University of Science and Technology-Khartoum-Sudan*
**Corresponding author: Caroline Edward Ayad[1]*

Abstract : *Morphometric measurements of the corpus callosum (CC) are important to have normative values according to gender, age and race/ethnicity. The present study examined the correlation between age, gender, and CC morphometrical data, across ages <10>60 years old to characterize normal developmental alternations in order to be as standard local reference for Sudanese. At issue; the objectives are also to examine whether CC index continues to increase throughout life, whether there are regional differences in measurements of CC maturation, and whether these outlines are sexuallydimorphic.*

The CC on Magnetic Resonance midsagittal T_1 weighted images was measured in 233 normal Sudanese subjects, (126 were males constituting 54.1% and 107 were females constituting 45.9%) admitted to Modern Medical Center, Royal care international hospital, MRI centers Khartoum-Sudan.

Considering age and gender; Fronto occipital maximum brain length, Thickness of CC compartments at its maximum level for rostrum, genu, body/trunk and splenium, CC greatest anteroposterior (AP)diameter, fronto-corpus callosum length, occipito-corpus callosum length and corpus callosum index (CCI) were measured. Data were analyzed using SPSS programe (Ver.16). All dimensions of CC compartments and brain have significant relation with increasing age at p=0.000 except for occipito-corpus callosum length where no significant relation was detected (p=0.126). The gender has an impact on the changes detected in the brain and CC compartments except for the rostrum, genu, callosal AP maximum diameter. Brain dimensions were significantly larger in males than in females at ($P \leq 0.05$). Reverse findings were found in the CC trunk, splenium maximum thickness and CCI, where females were greater than males with significant difference at P= 0.000, 0.011 and 0.031 respectively .The CCI increased with age and then decreased thereafter. There was also a positive linear relationship between the AP length of the CC and the fronto-corpus callosum length. Regression equation for predicting the length of the CC and morphometric index as local reference for normative data of CC during maturation in the Sudanese population in both genders at similar age classes have beenestablished.

Keywords *- corpus callosum, morphometry, MRI*

I. INTRODUCTION

Neuroimaging of the corpus callosum(CC) has attracted the researchers in both medical and neuroscience awareness in the past few decades.[1]Callosal changes due to brain atrophy were characterized in many diseases [2-4]as well the abnormalities in callosal morphology have also been reported in neuropsychiatric disorders[5] , developmental disorders[6] also changes are found during normal human development and aging [7], with callosal morphology reflecting gender differences [8]. Regarding differences in the size of humans‘organs including CC according to race/ethnicity; CC dimensions, morphology and sex-related differences have been of interest to investigators. [9]

Most of the studies on the morphometrery of CC were carried out in Western countries on the Caucasian population [10-14] and a few studies were performed in the East Asian population [15,16]Minimal variability in the dimensions and relative dimensions of the CC in Greek people was reported [9]. Takada in 2003 did not observe any difference in the regional size of CC between genders in Japanese subjects [15] On the other hand; another study found a well established difference in size, shape and position of the CC between genders. [11]

Magnetic resonance imaging (MRI) provides the most resolute images of the CC compared with the other imaging modalities [17].

To the best of our knowledge; no study has been obtained for Sudanese to characterize the norms, as clearly; there is a lack of comprehensive reference data with respect to callosal maturation. All data were interrelated to American, European, or Asian populations. In the present study we examine the correlation between age, gender, and CC morphometrical analyses using MRI, across ages

<10>60 years old to characterize normal developmental alternations in order to be as standard local

reference for Sudanese residence in central Sudan .knowledge about the norms might eases the early prediction of disorders if happened. At issue; the objectives are also to examine whether CC index continues to increase throughout life or reaches adult levels at earlier ages, whether there are regional differences in measurements of CC maturation, and whether these outlines are sexually dimorphic for Sudanese populations.

II. MATERIALS ANDMETHODS

This study is a descriptive cross-sectional study conducted at Modern Medical Center and Royal Care International Hospital. This study was carried out using MRI scanner of 1.5 Tesla (Toshiba) during the period from August 2014– 2017.

2.1 Population:

This study included males and females with normal corpus callosum , their age ranged between 1 -83 years. Patients were excluded only when the pathologic process affected, or could affect, the corpus callosum (e.g., hydrocephalus or tumor) and when the entire corpus callosum was not on a single slice as a consequence of an oblique imaging plane. Magnetic resonance images were eliminated if there was any visible evidence of deviation from the midsagittalplane.

2.2 Sample size andtype:

A convenient sample type was adapted, where a total of 233 patients (126 males constituting 54.1% and 107 females constituting 45.9%) present for Brain MRI scan were included in the study in respect to the inclusion criteria. Considering the gender subjects were grouped as <10, 11-20 , 21-30, 31- 40,41-50 ,51-60 and >60year old.Distribution of the total study sample age were as follows: <10=(24, 10.3%),11-20=(33,14.2%),21-30=(37,15.9%),31-40=(49,21.0%),41-50=(40,17.2%),51-60=(17, 7.3%) and >60=(33, 14.2%), the study sample mean age was 36.72±20.77.The 126 males mean ages were classified into age classes as follows : Ages <10 =(4.084 ±23.02) ages from 11-20 =(13.30±3.23) and 21-30 were (26.06±2.69), 31-40were(36.56±2.93),ages from 41-50were(46.00±2.91) ,51-60were (56.00±3.16) and ages >60were 72.88±6.71. The 107 females mean ages were classified into age classes as follows: Ages <10= (3.40±1.34), ages between 11-20 were (16.30±2.45) ages from 21-30were (26.09±3.16), 31-40were (36.26±2.44) ages from 41-50 were (47.04±2.78), 51-60 were 55.55±2.06 and ages >60 were (70.85±5.63).

2.3 Methods:

2.3.1 Techniques:

Head coil was used with a sheet on the table, dentures, hair clips, hair combs, earrings, nose rings, necklaces, were removed .Patients were positioned so their head and neck are relaxed, but without rotation in either plane, centre the field of view on the nasion in the midline, making minor adjustments for baselinetilt.

2.3.2 Measurement:

Data collection sheet were used to collect data about demographic characteristics (gender and age). In this study various parameters of corpus callosum were measured in Sudanese at the mid-sagittal plane of T_1 MR Images as described by Figueira et al. 2007[18]. The considered variableswere:-

- Fronto occipital maximumlength.
- Thickness of various parts of corpus callosum at its maximum level (rostrum, genu, body/trunk and splenium).
- Greatest Anteroposterior Diameter Of corpuscallosum.
- Fronto-Corpus Callosum length (Distance of corpus callosum from frontal pole) and Occipito-Corpus Callosum length (occipital pole of cerebralhemisphere).
- Corpus callosum index(CCI)

Corpus callosum index (CCI) was obtained on a conventional best midsaggital T1W image, using a simple orthogonal semi-automated system, by drawing a straight line at greatest anteroposterior diameter of CC and a perpendicular at its midline, owing to points genue maximum thickness, trunk maximum thickness and maximum thickness length of CC were measured and normalized to its greatest anteroposterior diameter (from genu to splenium), CCI was found for each cases, one by one, from the calculated measurements by ***Formula*** applied previously by Mehmet et al 2012 [19]

Corpus callosum index (CCI) = (Genue maximum thickness + Trunk maximum thickness + Splenium maximum thickness /(CC greatest anteroposterior diameter)

2.3.3 Method of dataanalysis:

The Obtained data were transferred to SPSS (ver. 16.0) programme and were analyzed and presented as mean, standard deviation, and normal curve as well as significant differences between the different age groups was tested

III. FIGURES AND TABLES

Table 1 Descriptive statistics of the dimensions of Corpus Callosum (CC) and Brain in Sudanese population

Descriptive Statistics					
Morphometric index	N	Min(mm)	Max(mm)	Mean(mm)	STDV
Fronto Occipital Length	233	70.00	196.00	165.03	11.39
CC greatest anteroposterior diameter	233	52.00	163.00	74.33	7.49
Rostrum Maximum Thickness	233	0.30	3.00	1.24	.50
Genu Maximum Thickness	233	5.00	18.00	11.56	2.39
Trunk Maximum Thickness	233	2.70	9.00	6.21	1.34
Splenium Maximum Thickness	233	3.70	15.00	10.64	2.18
Fronto-Corpus Callosum Length	233	3.00	51.20	36.32	4.22
Occipito-Corpus Callosum Length	233	40.00	72.00	55.98	5.42
Corpus Callosum Index	233	0.034	0.514	0.37	0.06
CC greatest anteroposterior diameter /Fronto occipital length ***(Ratio)is*** **74.33/165.03=0.45**					

Table 2 Descriptive statistics of the Brain dimensions in Sudanese population classified according to age

Descriptive							**P-value**
		N	Mean	STDV	Min	Max	
Fronto Occipital Length	<10	24	154.04	13.06	132.00	177.00	0.000
	11-20	33	163.67	10.49	143.00	196.00	
	21-30	37	166.37	8.44	153.00	190.00	
	31-40	49	168.85	7.46	154.00	186.00	
	41-50	40	164.92	16.71	70.00	187.00	
	51-60	17	166.19	8.64	153.00	180.00	
	>60	33	166.71	6.84	154.00	180.00	
	Total	233	165.03	11.39	70.00	196.00	
Fronto-Corpus Callosum Length	<10	24	38.78	3.52	32.00	44.00	.015
	11-20	33	36.91	3.71	29.00	47.00	
	21-30	37	36.20	3.27	31.00	48.00	
	31-40	49	34.89	5.49	3.00	42.00	
	41-50	40	36.22	3.10	30.00	46.00	
	51-60	17	37.17	5.84	32.00	51.20	
	>60	33	35.89	3.39	29.00	44.00	
	Total	233	36.32	4.22	3.00	51.20	
Occipito-Corpus Callosum Length	<10	24	55.45	6.55	43.00	65.00	.126
	11-20	33	56.54	5.71	44.00	67.00	
	21-30	37	56.54	5.21	47.00	72.00	
	31-40	49	57.50	4.88	48.00	68.00	
	41-50	40	54.62	5.08	44.00	63.00	
	51-60	17	53.91	5.11	46.60	63.00	
	>60	33	55.63	5.46	40.00	67.00	
	Total	233	55.98	5.42	40.00	72.00	

Table 3: Dimensions of Corpus Callosum compartments in Sudanese population classified according to age

Morphometric index	Age Class	N	Mean	Std.	Min	Max	P-value
CCAPD/(mm)	<10	24	61.50	6.69	52.00	80.00	0.000
	11-20	33	70.80	6.88	55.00	84.00	
	21-30	37	75.18	5.88	63.00	87.00	
	31-40	49	77.58	5.34	66.00	89.00	
	41-50	40	79.77	14.26	67.00	163.00	
	51-60	17	76.13	5.19	67.00	88.00	
	>60	33	76.93	5.30	67.00	92.00	
	Total	233	74.76	9.45	52.00	163.00	
RML/(mm)	<10	24	.77	.41	.30	2.40	0.000
	11-20	33	1.07	.43	.50	2.40	
	21-30	37	1.34	.43	.80	2.50	
	31-40	49	1.52	.46	1.00	3.00	
	41-50	40	1.31	.45	.80	2.60	
	51-60	17	1.35	.59	.50	2.80	
	>60	33	1.09	.48	.50	2.40	
	Total	233	1.24	.50	.30	3.00	
GML/(mm)	<10	24	8.81	1.97	5.00	13.00	0.000
	11-20	33	10.90	2.15	7.60	15.00	
	21-30	37	12.68	1.71	8.00	16.00	
	31-40	49	13.03	2.20	7.00	18.00	
	41-50	40	12.45	1.66	9.00	16.00	
	51-60	17	10.98	2.11	7.00	14.00	
	>60	33	10.01	1.85	7.00	15.00	
	Total	233	11.56	2.39	5.00	18.00	
BML/(mm)	<10	24	4.63	1.37	2.70	7.50	0.000
	11-20	33	5.88	1.29	4.00	8.00	
	21-30	37	6.75	.96	4.40	9.00	
	31-40	49	6.83	.98	4.70	9.00	
	41-50	40	7.05	.86	6.00	9.00	
	51-60	17	5.99	.75	5.00	7.00	
	>60	33	5.25	1.23	3.00	9.00	
	Total	233	6.21	1.34	2.70	9.00	
SML/(mm)	<10	24	7.88	1.57	4.00	10.00	0.000
	11-20	33	10.21	2.55	3.70	15.00	
	21-30	37	11.28	1.69	7.40	15.00	
	31-40	49	11.18	1.85	6.00	14.00	
	41-50	40	11.92	1.73	8.00	15.00	
	51-60	17	11.32	1.73	8.00	14.00	
	>60	33	9.66	1.64	7.00	13.00	
	Total	233	10.64	2.18	3.70	15.00	
CCI	<10	24	.34	.05	.267	.47	0.000
	11-20	33	.37	.08	.034	.51	
	21-30	37	.41	.04	.310	.50	
	31-40	49	.40	.04	.287	.48	
	41-50	40	.39	.07	.038	.50	
	51-60	17	.37	.04	.314	.45	
	>60	33	.33	.05	.236	.46	
	Total	233	.37	.06	.034	.51	

CCGAPD Stands for *CC anteroposterior diameter, RMT* for *Rostrum Maximum Thickness* ,GMT for *Genu Maximum Thickness,* for *TMT Trunk Maximum Thickness,* for *SMT =Splenium Maximum Thickness, and CCI* for *Corpus Callosum Index* .***(sig atp≤0.05)***

Table 4 Morphometric index/ chart established for brain and Corpus Callosum dimensions in Sudanese population for both genders at similar age classes

Morphometric index	Gender	Age Classes						
		<10	11-20	21-30	31-40	41-50	51-60	>60
FOL/(mm)	Male	154.42 ±13.5	169.3 ±5.35	171.31 ±8.50	171.30 ±7.19	163.05 ±24.76	170.21 ±7.95	167.60 ±6.98
	Female	152.60 ±12.17	161.21 ±11.30	162.61 ±6.29	165.00 ±6.30	166.30 ±6.68	162.62 ±7.97	163.42 ±5.50
CCAPD/(mm)	Male	62.00 ±7.19	70.40 ±7.47	75.18 ±6.41	78.26 ±5.19	84.05 ±20.83	76.66 ±6.82	76.69 ±5.71
	Female	59.60 ±4.33	70.98 ±6.77	75.19 ±5.61	76.50 ±5.55	76.60 ±4.49	75.66 3.57	77.85 ±3.57
RMT/(mm)	Male	.80 ±.44	1.13 ±.49	1.42 ±.53	1.54 ±.39	1.46 ±.454	1.40 ±.79	1.08 ±.47
	Female	.66 ±.194	1.05 ±.420	1.27 ±.33	1.51 ±.55	1.20 ±.43	1.32 ±.38	1.12 ±.57
GMT/(mm)	Male	9.02 ±2.03	10.57 ±2.32	12.36 ±1.86	13.08 ±2.22	12.64 ±1.57	11.62 ±2.26	9.70 ±1.35
	Female	8.02 ±1.63	11.04 ±2.10	12.93 ±1.59	12.94 ±2.23	12.30 ±1.74	10.41 ±1.92	11.14 ±2.96
TMT/(mm)	Male	4.62 ±1.45	5.15 ±1.32	6.58 ±1.14	6.85 ±1.04	6.88 ±.78	6.08 ±.79	4.98 ±.90
	Female	4.68 ±1.21	6.20 ±1.16	6.89 ±.81	6.79 ±.90	7.18 ±.91	5.91 ±.75	6.27 ±1.80
SMT/(mm)	Male	7.70 ±1.57	9.36 ±2.65	11.00 ±2.08	11.43 ±1.79	11.97 ±2.13	11.30 ±1.97	9.46 ±1.54
	Female	8.58 ±1.51	10.58 ±2.47	11.50 ±1.33	10.78 ±1.93	11.87 1.41	11.35 ±1.59	10.42 ±1.90
FCCL/(mm)	Male	39.04 ±3.61	38.90 ±3.17	37.37 ±3.91	36.16 ±3.01	37.00 ±3.26	39.98 ±6.88	36.09 ±3.73
	Female	37.80 ±3.34	36.05 ±3.65	35.30 ±2.42	32.89 ±7.68	35.65 ±2.91	34.66 ±3.46	35.14 ±1.67
OCCL/(mm)	Male	54.89 ±7.01	59.80 ±5.99	59.06 ±5.07	58.69 ±5.35	53.58 ±4.80	54.45 ±6.18	55.88 ±5.77
	Female	57.60 ±4.33	55.12 ±5.08	54.61 ±4.53	55.64 ±3.39	55.39 ±5.24	53.44 ±4.27	54.71 ±4.38
C.C.I	Male	0.34 ±.05	0.35 ±.05	0.39 ±.044	0.40 ±.05	0.40 ±.04	0.37 ±.04	0.32 ±.05
	Female	0.35 ±.04	0.37 ±.09	0.41 ±.03	0.39 ±.03	0.39 ±.09	0.36 ±.03	.35 ±.06

FOL Stands for *Fronto Occipital Length , CCAPD for CC greatest anteroposterior diameter,RMT for Rostrum Maximum Thickness* ,GMT for *Genu Maximum Thickness,* for *TMT Trunk Maximum Thickness,* for *SMT =Splenium Maximum Thickness, FCCL* for *Fronto-Corpus Callosum Length,OCCL* for *Occipito-Corpus Callosum Length, and CCI* for *Corpus Callosum Index*

Table 5: Dimensions of Brain and Corpus Callosum compartments in Sudanese population classified according to gender with independent Samples Test.

Group Statistics					Independent Samples Test	
					Means	
Morphometric index	**Gender**	N	Mean	STDV	t	Sig. (2-tailed)
Fronto Occipital Length	Male	126	166.65	13.23	2.38	.018
	Female	107	163.11	8.43		
CC anteroposterior diameter	Male	126	75.15	11.36	.67	.499
	Female	107	74.31	6.56		
Rostrum Maximum Thickness	Male	125	1.27	.54	.82	.410
	Female	107	1.21	.46		
Genu Maximum Thickness	Male	126	11.33	2.45	-1.59	.112
	Female	107	11.83	2.30		
Trunk Maximum Thickness	Male	126	5.91	1.41	-3.77	.000
	Female	107	6.56	1.16		
Splenium Maximum Thickness	Male	126	10.31	2.34	-2.57	.011
	Female	107	11.04	1.92		
Fronto-Corpus Callosum Length	Male	126	37.31	3.88	3.99	.000
	Female	107	35.16	4.31		
Occipito-Corpus Callosum Length	Male	126	56.71	5.98	2.25	.025
	Female	107	55.12	4.55		
Corpus Callosum Index	Male	126	.37	.05	-2.17	.031
	Female	107	.38	.06		

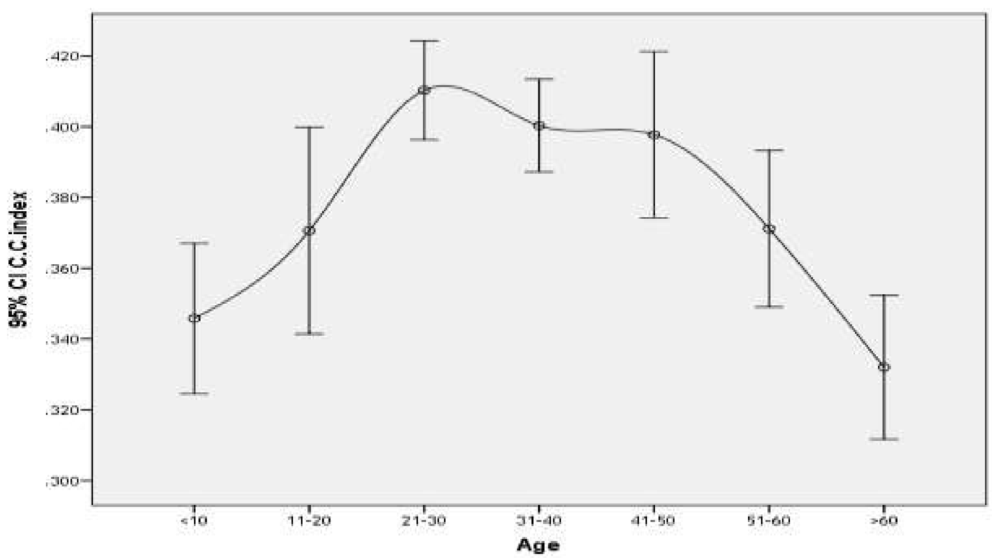


Figure (1) The maturation of corpus callosum considering the index and age classes during life development.

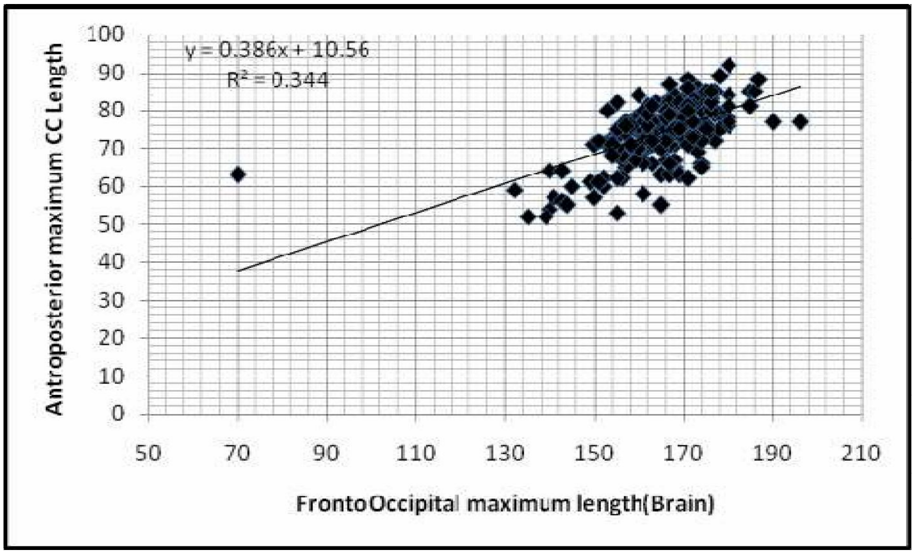


Figure (2) A scatter plot diagramme shows the linear relationship between the fronto occipital maximum length and CC maximum AP diameter. As the FOML increases the CCMAPD increase by 0.39 mm starting from 10.56 mm {the contribution of the FOML to do change in the CC measurement is 34%} ,{regression equationy=0.386x+10.56}

IV. DISCUSSION

The (CC) is the major commissure connecting the cerebral hemispheres and there is evidence of its continuing development into young adulthood [20] However, few are known about changes in the characteristics of the CC compartments. Table (1) shows the measurements of the brain and the CC compartments for Sudanese measured in (mm). CC greatest anteroposterior diameter to Fronto occipital length *(Ratio) was* 0.45, that means it is around half of the brain measurement, the relation between them can be justified as that the segments of the CC (genu, body, rostrum and splenium) are topographically organized to carry interhemispheric fibers representing brain cortex and the development of each of these regions can provide approaching into the brain development. [21]The anatomical relation between the CC and brain is that CC is the main fiber tract connecting the two cerebral hemispheres.[22]These data reflect the fact that the fronto callosal maximum distance and CCMAPD have an association, as seen in figure (2) that shows the linear relationship between the two variables. As the FOML increases the CCMAPD increase by 0.39 mm starting from its measurementof

10.56 mm , the contribution of the FOML to do change in the CC measurement is 34%. Regarding the relation between the brain and CC dimensions in our study, we concluded that there is symmetry between the brain and the measurement of CC. This result is similar to Estruch *et al.* [23] and Mourgela *et al.'s* study (9) and another Iranian study [24]. Regression equation has been established for Sudanese CC: y=0.386 x+10.56; Corpus callosum maximum AP diameter (mm) = 0.386 X Frontocorpus maximum diameter (mm) +10.56.

We studied the age-related changes in the measurements of the brain and maximum thickness of the four compartments of the CC in the MRI scans of 233 healthy Sudanese individuals aged

<10>60 years. The impact of age has been studied comprehensively as noticed in table (2) and (3). Fronto Occipital Length was found to be as maximum value at the age between 31-40 years with significant relation with the age except for occipital callosal length where no significant relation between this part and advancing age p=0.126. Total midsagittal measurements of the corpus callosum for all its compartments increased significantly across the age span although significant increases were limited to occipito-corpus callosum length. Fronto-CC maximum value was found in the age <10 and measured 38.78mm. CCAPD/(mm)reached its maximum at the age of 41-50 (79.77mm) ,RML at 31- 40(1.52mm), GML at 31- 40(13.03mm) ,BML at 41-50(7.05mm),SML at 41-50(11.92mm) and CCI

maximum maturation value at the age between21-30(0.41).

Table (4) presented morphometric index/ chart established for brain and CC dimensions in Sudanese population for both genders at similar age classes.

In our study without considering the gender, according to age group we observed development of CC continued and showed statistical significant relationship between the age and its compartments at ($p< 0.05$).The significant relation between the fronto- occipital diameter of brain with age; and the maturation of the genue; is that they are correlated to each other's where the genu region is linked with the prefrontal cortex[25]A similar view by Luders et al was given ,they stated that genue growth may start in late adolescent period when frontal lobe is actively developed.[7] that is where the maximum value for the genue was found at the ages between 31-70years in our study. Keshavan et al, has reported that between children and adolescent and between adolescent and young adults, the genu region is significantly increasing.[25] However, in their study, the distribution of age groups is obviously doesn't match with the age group in our recentstudy.

The gender has an impact on the changes detected in the brain and CC compartments except for the rostrum, genu, callosal AP maximum diameter. In a study done in Iranian population [24], there was no significant difference detected in CC diameters between genders. and they were similar to the findings of Takeda's study in Japan [15]and Tuncer's study in Turkey [26].The current study showed that there is significant difference between the splenium in both genders as noticed in table(5).This findings was of reverse results to studies of human CC, who mentioned the insufficient evidence to support the presence of sex related differences in the size or shape of the splenium[27] other study showed no gender related difference of splenium in the Japanese [15]and in the Indians [28,29]. Another study showed no significant difference in splenial width found between males and females [30]. Another study found a significant gender related differences in the thickness of splenium.[24] However, on the basis of our findings in the present study, one can conclude that Sudanese differs from other population and there is significant sexual dimorphism in splenium .The differences on quantitative data of CC in various areas of the world which were seen in different studies may be due to racial/ethnicfactors.[15,30]

Brain dimensions were significantly larger in males than in females ($P < 0.05$),and reverse findings were found in the CC trunk maximum thickness, splenium maximum thickness and CCI where females were greater than males with significant difference at 0.000,0.011 and 0.031 respectively as noticed in table(5), similar results was mentioned by De- Lacoste-Utamsing and Holloway 1982 [31].Some studies have reported greater width of trunk in females, [32,33] These findings were observed in our study .Another studies showed larger genu in males [32 ,34]and a larger anterior trunk in males. [32] Most studies have failed to find any evidence of sexual dimorphism in CC. Some studies have reported greater splenial width and area in females.[35-37]Bishop and Wahlstein[27] Witelson[32] also did not report any gender related differences in splenial areas. Similarly, an Indian study [34] also failed to find gender related difference in splenium. Our results concerning Sudanese were not in agreement with most of theliterature.

The maturation of the CC has been described to begin at approximately 8 to 10 weeks of gestation.[38,39] Number of collosal fibers are fixed at birth, however, structural changes at CC continues due to myelinination of fibers during postnatal development, redirection, pruning and myelination.[39] The complete formation of CC continues to enlarge throughout infancy, childhood, and young adulthood.[40] Schaefer et al stated that growing of CC continues till the 15 year age and during this period it could be reflections of increasing the myelinisation of CC.[41]On the other hand Simon et al claimed growing of CC continues until the 18th year-old. [42] .In our study without considering the gender and according to age group we observed maturation of CC continued and showed significant increasing with age with maximum values for CCI were found at the ages between the 21-30 age and measured 0.41.One study done by Mehmet Ilkay Kosar 2012 [19] shows that the CCI was 0.44 ± 0.05 at the age 6-9 years, 0.46 ± 0.05 at 10-13 years and 0.45 ± 0.03 at the age 14-17 yearsold.

In our present study CCI showed significant difference between the two genders at p=0.031 ,CCI in males was 0.37 and in females was 0.38 ,it increased by increasing age and then it reduced thereafter figure(1) and table(5). Total midsagittal CCI (Splenum, body, Genu ,rostrum and CC maximunm AP length) increased strongly across this age span for both genders, although significant increases were limited for corpus to occipital brain regions. The maturation of brain and CC compartments across the age less than 10 and greater than 60 was presented in table (4) for both genders. It was considered as chart for Sudanese norms for development .The majority of maturational changes in the splenium of the CC across this age span suggests the anterior sections may have already reached their adult sizes in the childhood age 11-20 was (9.36±2.65) for males and (10.58±2.47) for females which is similar to the measures found at the age more than 60. This possibility was investigated by comparing our pediatric data to scans on adults subjects aged 20-60, acquired and analyzed in an identical approach, as noticed in table (4)

There were little differences between the adolescent and adult means in the rostrum; in the childhood ages between 11-20 and ages more than 60 for both genders as well the changes appears in the genu at the age group less than 10 years was found to be small for both males and females comparing to the subjects whose age greater than 60 years old. This is in contrast to the remaining mid and posterior part which was significantly smaller for the pediatric group. This supports the concept that the rostrum and genu plateau at adult sizes early in development.[43]

Ongoing development of the body/trunk of the CC is consistent with continued maturation of higher association well into adulthood, since a large amount of callosal fibers derived from these parts.[44] However aging affected this maturation, to be decreased by increasing age for both genders significantly. We had detected changes in the genue and restrum regions in both genders, the changes was found to be due to age but not statistically correlated with gender. Perhaps the increasing frontal connectivity patterns of adolescence involve mainly intra hemispheric, as opposed to inter hemispheric, structures. This anterior-to-posterior CC maturation, reflects anterior/posterior patterns of inter hemispheric myelination and connectivity during normal development [43]

V. CONCLUSION

All dimensions of CC compartments and brain have significant relation with increasing age at p=0.000 except for occipito-corpus callosum length where no significant relation was detected (p=0.126). The gender has an impact on the changes detected in the brain and CC compartments except for the rostrum, genu, callosal AP maximum diameter. Brain dimensions were significantly larger in males than in females at ($P \leq 0.05$). Reverse findings were found in the CC trunk, splenium maximum thickness and CCI, where females were greater than males with significant difference at P= 0.000, 0.011 and 0.031 respectively .The CCI increased with age and then decreased thereafter. There was also a positive linear relationship between the AP length of the CC and the fronto-corpus callosum length. Regression equation for predicting the length of the CC and morphometric index of CC in the Sudanese population in both genders at similar age classes has been established. A local reference for normative data of Sudanese brain and CC morphometric indices has been established during maturation for bothgenders.

Acknowledgements

We sincerely thank the participants without whom the study would not have been feasible. The Sudan University of Science and Technology, College of Medical Radiological Science and at Modern Medical Center and Royal Care International Hospital, Radiology Department –in which the study was obtained, are thankfully acknowledged.

REFERENCES

[1]. Timothy J. Herron, Xiaojian Kang and David L.Woods 2012Automated measurement of the human corpus callosum using MRI Frontiers in Neuro informatics www.frontiersin.org September |Volume6|Article25 | 1-15

[2]. DiPaola,M.,Spalletta,G., and Caltagirone,C.(2010). *In vivo* structural neuro anatomy of corpus callosum in Alzheimer's disease andmildcognitiveimpairmentusingdifferentMRItechniques:areview.*J.AlzheimersDis.*20,67–95.

[3]. Frederiksen, K.S.,Garde,E., Skimminge, A.,Ryberg,C., Rostrup,E.,Baaré,W.,Siebner, H.,Hejl, A.M.,Leffers,A.M.,and Waldemar,G.(2011b).Corpuscal- losum atrophy in patients with mild Alzheimer's disease. *Neurodegener. Dis.* 8, 476–482

[4]. Hasan,K.M.,Walimuni,I.S.,Abid, H.,Wolinsky,J.S.,and Narayana,P. A. (2012b).Multi-modal quantitative MRI investigation of brain tissue neuro degeneration in multiple sclerosis. *J.Magn.Reson.Imaging.* 35, 1300–1311.

[5]. Bearden,C.E.,VanErp,T.G.M., Dutton,R.A.,Boyle,C.,Madsen, S., Luders,E., Kieseppa,T., Tuulio- Henriksson,A., Huttunen,M., and Partonen,T.(2011).Mapping cor- pus callosum morphology in twin Pairs discordant for bipolar disorder. *Cereb.Cortex* 21, 2415–2424.

[6]. Paul,L.K .(2011).Developmental malformation of the corpus callosum: a review of typical callosal development and examples of developmental disorders with callosal involvement. *J. Neurodev.Disord.* 3, 3–27.

[7]. Luders E, Thompson PM, Toga AW. 2010The development of the corpus callosum in the healthy human brain. J Neurosci.;18;30(33):10985-10990

[8]. Gurd,J.M.,Cowell, P.E.,Lux,S., Rezai, R.,Cherkas,L.,and Ebers,G.C. (2012). fMRI and corpus callosum relationships in monozygotictwinsdiscordantforhandedness.*BrainStruct.Funct.*doi:10.1007/s00429-012-0410-9.

[9]. Mourgela S, Anagnostopoulou S, Sakellaropoulos A, Gouliamos A. 2007An MRI study of sex-and age-related differences in the dimensions of the corpus callosum and brain. *Neuroanatomy*.;6(1):63-5.10-14

[10]. Peterson BS, Feineigle PA, Staib LH, Gore JC. 2001Automated measurement of latent morphological features in the human corpus callosum.*Hum BrainMapp*.;12(4):232-45.

[11]. Bermudez P, Zatorre RJ. 2001Sexual dimorphism in the corpus callosum: methodological considerations in MRImorphometry.
Neuroimage.;13(6 Pt 1):1121-30.

[12]. Luders E, Narr KL, Zaidel E, Thompson PM, Toga AW. 2006Gender effects on callosal thickness in scaled and unscaled space.
Neuroreport.;17(11):1103-6.

[13]. Sullivan EV, P fefferbaum A, Adalsteinsson E, Swan GE, Carmelli D. 2002Differential rates of regional brain change in callosal and ventricular size: a 4-year longitudinal MRI study of elderly men. *Cereb Cortex*.;12(4):438-45.

[14]. Luders E, Rex DE, Narr KL, Woods RP, Jancke L, Thompson PM,et al. 2003Relationships between sulcal asymmetries and corpuscallosumsize:genderandhandednesseffects.*CerebCortex*.;13(10):1084-93.

[15]. Takeda S, Hirashima Y, Ikeda H, Yamamoto H, Sugino M, Endo S. 2003Determination of indices of the corpus callosum associatedwithnormalaginginJapaneseindividuals.*Neuroradiology*.;45(8):513-8.

[16]. Okamoto K, Ito J, Tokiguchi S. 1990 [The MR findings on the corpus callosum of normal young volunteers]. *Nihon Igaku HoshasenGakkai Zasshi*.;50(8):954-63

[17]. Reinarz SJ, Coffman CE, Smoker WRK, Godersky JC. 1988MR imaging of corpus callosum: Normal and pathologic findings and correlationwith CT. *AJNR*; 9:649-56.

[18]. Figueira FF, Santos VS, Figueira GM, Silva AC. 2007Corpus callosum index: a practical method for long-term follow-up in multiple sclerosis. Arq Neuro psiquiatr.; 65(4A):931-935.

[19]. Mehmet Ilkay Kosar, Fatma Hayat Erdil, Vedat Sabanciogullari,Keziban Karacan, Mehmet Cimen, Mehmet 2012 A talar Morphometry of Corpus Callosum Related with Gender and Age: Magnetic Resonance Imaging Study Pak J Med Sci April -
June Vol. 28 No. 3 408-412

[20]. Pujol J, Vendrell P, Junque C, Marti-Vilalta JL, Capdevila A. 1993When does human brain development end? Evidence of corpuscallosumgrowthuptoadulthood.AnnalsofNeurology;34:71–5.

[21]. Matcheri S. Keshavan, Vaibhav A. Diwadkar, Michael DeBellis,Elizabeth Dick, Rupali Kotwal, David R. Rosenberg, John A. Sweeney,Nancy Minshew, Jay W. Pettegrew (2002) Development of the corpus callosum in childhood,adolescence and early adulthood Life Sciences 70 1909–1922

[22]. Eileen Luders, Paul M. Thompson, Arthur W. Toga 2010 The Development of the Corpus Callosum in the HealthyHuman Brain The Journal of Neuroscience, 30(33):10985–10990 • 10985

[23]. Estruch R, Nicolas JM, Salamero M, Aragon C, Sacanella E, Fernandez-Sola J, et al. 1997Atrophy of the corpus callosum in chronic alcoholism. *J NeurolSci*.;146(2):145-51.

[24]. Mohammad Reza Mohammadi , Pouya Zhand , Behnoush Mortazavi Moghadam , Mohammad Jafar Golalipour . Iran 2011Measurement of the Corpus Callosum Using Magnetic Resonance Imaging in the North of Iran J Radiol.;8(4):218-223.
DOI: 10.5812/iranjradiol.4495

[25]. Keshavan MS, Diwadkar VA, DeBellis M, Dick E, Kotwal R,Rosenberg DR, et al. 2002Development of the corpus callosum in childhood, adolescence and early adulthood. Life Sci.;70(16):1909-1922.

[26]. Tuncer MC, Hatipoglu ES, Ozates M. 2005Sexual dimorphism andhandedness in the human corpus callosum based on magnetic resonance imaging. *Surg Radiol Anat*.;27(3):254-9.

[27]. Bishop KM, Wahlstein D (1997): Sex differences in the human corpus callosum: myth or reality? Neurosci Biobehav Rev 1997; 21:581-601.

[28]. BankaS,JitI. 1996Sexualdimorphisminthesizeofthecorpuscallosum.JAnatSocofIndia;45:77-85.

[29]. Suganthy J, Raghuram L, Antonisamy B, Vettivel S, Madhavi C, Koshi R. 2003Gender and Age related differences in the morphology of the corpus callosum. Clin Anat; 16: 396-403.

[30]. Gupta T, Singh B, Kapoor K, Gupta M, Kochhar S.. 2009Normative Data of Corpus Callosal Morphology in a North-West IndianPopulation-AnautopsyandMRIstudy.JNepalMedAssoc;48:46-51.

[31]. De Lacoste-Utamsing, C., and Holloway, R. L. 1982. Sexual dimorphism in the human corpus callosum. *Science* 216: 1431–1432.

[32]. Witelson SF. 1989Hand and sex differences in the isthmus andgenu of the human corpus callosum. A postmortem morphological study. *Brain*; 112: 799-835

[33]. Clarke JM, Zaidel E. 1994Anatomical–behavioral relationships:corpus callosum morphometry and hemispheric specialization.*Behav Brain Res*; 64: 185-202.

[34]. BankaS,JitI. 1996Sexualdimorphisminthesizeofthecorpuscallosum. *JAnatSocIndia*;45:77-85

[35]. Allen LS, Richey MF, Chai YM, Gorski RA. Sex differencesin the corpus callosum of the living human being. *J Neurosci*1991; 11:933-42.

[36]. Holloway RL, Anderson PJ, Defendini R, Harper C. 1993Sexual dimorphism of the human corpus callosum from three independent samples: Relative size of the corpus callosum.*Amer J of Phys Anthropol*; 92: 481-98.

[37]. Davatzikos C, Resnick SM. 1998Sex difference in anatomic measuresof interhemispheric connectivity: Correlations with cognition in women but not men. *Cereb Cortex*; 8: 635-40.

[38]. Barkovich JA, Kjos BO. 1988Normal postnatal development ofthe corpus callosum as demonstrated by MR imaging. Am J Neuroradiol;9:487-491.

[39]. Barkovich JA, Norman D. 1988Anomalies of the corpuscallosum: correlation with further anomalies of the brain.Am J Roentgenol.;51:171-179.

[40]. Dubovsky EC, Booth TN, Vezina G, Samango-SprouseCA, Palmer KM, Brasseux CO. 2001MR imaging of the corpus callosum in pediatric patients with neurofibromatosis type1. Am J Neuroradiol.;22(1):190-195.

[41]. Schaefer GB, Thompson JN, Bodensteiner JB. 1990Quantitative morphometric analysis of brain growth using magnetic resonance imaging. J ChildNeurol.;5:127-130.

[42]. Simon JH, Schiffer RB, Rudick RA, Herndon RM. 1987Quantitative determination of MS-induced corpus callosum atrophy in vivo using MR imaging. Am JNeuroradiol.;8:599-604.

[43]. Jay N. Giedd , Judith M. Rumsey, F. Xavier Castellanos, Jagath C. Rajapakse, Debra Kaysen,A. Catherine Vaituzis, Yolanda C. Vauss, Susan D. Hamburger, Judith L. Rapoport 1996 A quantitative MRI study of the corpus callosum in children and adolescents, Developmental Brain ResearchVolume 91, Issue 2, , Pages 274-280

[44]. Pandya, D.N. and Rosene, D.L., 1985Some observations on trajectories and topography of commissural fibers. In A.G. Reeves (Ed.),*EpilepsyandtheCorpusCallosum*, Plenum,NewYork,,pp.21-35.

*Caroline Edward Ayad. "A Quantitative MRI Study of the Normative Corpus Callosum in Sudanese." IOSR Journal of Dental and Medical Sciences (IOSR-JDMS) 16.7 (2017): 77-86.

Available Online at http://www.journalajst.com

ISSN: 0976-3376

ASIAN JOURNAL OF SCIENCE AND TECHNOLOGY

Asian Journal of Science and Technology
Vol. 08, Issue, 10, pp.5871-5873, October, 2017

RESEARCH ARTICLE

CHARACTERIZATION OF CORPUS COLLOSUM IN MR IMAGES USING TEXTURE ANALYSIS

***Amna M. Ahmed, Suhaib Alameen, Caroline Edward Ayad and Mohamed E. M. Gar-Elnabi**

College of Medical Radiological Science, Sudan University of Science and Technology, Khartoum, Sudan

ARTICLE INFO

Article History:
Received 22nd July, 2017
Received in revised form
14th August, 2017
Accepted 03rd September, 2017
Published online 09th October, 2017

Key words:
Corpus collosum,
MRI, Texture analysis, FOS

ABSTRACT

This study concern to characterize the corpus collosum parts to splenium, trunk and genu using first order statistic and extract classification features from MR images. The FOS techniques included eight's features. To find the gray level variation in MR images it complements the FOS features extracted from MR images with variation of gray level in pixels and estimate the size variated of the sub patterns. analyzing the image with Interactive Data Language IDL software to measure the grey level variation of images. The results show that the first order statistic and features give classification accuracy of corpus collosum parts for splenium 100.0%, trunk 76.5% and the genu classification accuracy 97.0%. The overall classification accuracy of corpus collosum area 96.2%. These relationships are stored in a Texture Dictionary that can be later used to automatically annotate new MR images with the appropriate corpus collosum area names.

INTRODUCTION

The corpus callosum (CC) is the primary neuronal fiber tract connecting the two hemispheres of the brain and allows for transfer and integration of sensory, motor, and cognitive information (Wahl, 2007). Anatomically, in a clockwise direction, it is separated into the following four components: rostrum, genu, body, and splenium. Formation of the corpus callosum depends on a series of complex, highly regulated developmental events that begins during gestation and continues until adulthood (Rakic, 1968). The disruption of one or more of these events can result in agenesis of the corpus callosum (ACC), a disorder characterized by the complete or partial loss of one or more components of the corpus callosum (Dobyns, 1998). ACC is the most common developmental brain malformation occurring in 1.8 per 10,000 live births and in up to 50 % of individuals who are born with other brain malformations (Jeret, 1985). The classification of Magnetic Resonance (MR) image data, more specifically the classification of MR image data according to the nature of the corpus callosum. The corpus callosum is a highly visible structure in MR images whose function is to connect the left hemisphere of the brain to the right hemisphere, and be responsible for communication between these two hemispheres. The specific application used to illustrate the described classification process is the categorization of MR images into one of two classes: (i) musicians and (ii) non-musicians. However, the process has more general applicability. The classification process commences with the segmentation of the input images. With respect to the specific application reported here this is to identify the corpus callosum. For this purpose a variation of a standard image segmentation technique, spectral segmentation, is introduced.

Brain MR images describe particular a specific structure in these images called the corpus callosum. An example image is given in *Fig 1*. The corpus callosum is located in the centre of the image, the fornix is a related structure which often "blurs" into the corpus callosum and presents a particular challenge in the context of segmentation. The corpus callosum is of interest to medical researchers for a number of reasons. The size and shape of the corpus callosum have been shown to be correlated to sex, age, neurodegenerative diseases (such as epilepsy) and various lateralized behavior in people. It is conjectured that the size and shape of the corpus callosum reflects certain human characteristics (such as a mathematical or musical ability). It is a very distinctive feature in MRI brain scans. MRI can reveal disparate structural anomalies leading to similar clinical outcomes such as seizures and developmental delay. The corpus callosum is the principal supratentorial cerebral commissure (interhemispheric white matter tract).

It has traditionally been separated into four segments: the rostrum, genu, body, and splenium. Two smaller interhemispheric connections are located near the corpus callosum: the anterior commissure, which runs between the

**Corresponding author:* Amna M. Ahmed
College of Medical Radiological Science, Sudan University of Science and Technology, Khartoum, Sudan

amygdaloid nuclei, and the hippocampal commissure or psalterium, which connects the fornices and blends with the ventral aspect of the callosal splenium.

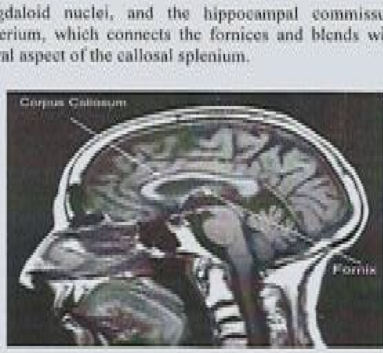


Fig. 1. Corpus callosum in a midsagittal brain MR images

Prior work has shown that anomalies of the corpus callosum, including agenesis (absence) and hypogenesis (presumed laterformed segments missing but earlier-formed segments present, sometimes referred to as "partial agenesis of the corpus callosum"), may be associated with a variety of other brain malformations (Atlas, 1986; Barkovich, 1988; Davila-Gutierrez, 2002; Barkovich, 2003; Byrd, 1990 and Barkovich, 2001).

MATERIALS AND METHODS

This study will include male and female with normal corpus callosum their age ranged between 20-85 years, a convenient sample type will be adapted, where a total of 200 patient present for Brain MRI scan.

Patients were excluded only when the pathologic process affected, or theoretically could affect, the corpus callosum (e.g., hydrocephalus or tumor) and when the entire corpus callosum was not on a single slice as a consequence of an oblique imaging plane. Magnetic resonance images were eliminated if there was any visible evidence of deviation from the midsagittal plane.

Techniques: Patient undergo to MRI department for MRI brain, use the head coil with a sheet on the table, remove dentures, hair clips, hair combs, earrings, nose rings, necklaces, position the patient so their head and neck are relaxed, but without rotation in either plane, centre the field of view on the nasion in the midline, making minor adjustments for baseline tilt. Probability, to calculate texture. The main advantage of this approach is its simplicity through the use of standard descriptors (e.g. mean and variance) to characterize the power of the approach for discriminating between unique textures is limited in certain applications because the method does not consider the spatial relationship, and correlation, between pixels. For any surface, or image, grey-levels are in the range $0 \leq i \leq Ng - 1$, where Ng is the total number of distinct grey-levels. If N (i) is the number of pixels with intensity i and M is the total number of pixels in an image, it follows that the histogram, or pixel occurrence probability, is given by,

$$P(i) = \frac{N(i)}{M}$$

In general, seven features commonly used to describe the properties of the image histogram, and therefore image texture, are computed. These are: mean; variance; coarseness; skewness; kurtosis; energy; and entropy.

RESULTS

The classification showed that the corpus collosum areas were classified well from the rest of the tissues although it has characteristics mostly similar to surrounding tissue.

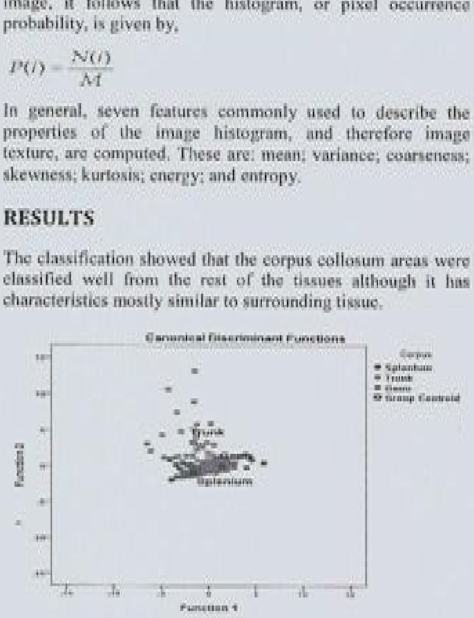


Fig. 2. Scatter plot generated using discriminate analysis function for three classes of corpus collosum; splenium, trunk and genu

Table 1. Showed the classification accuracy of the corpus collosum regions using linear discriminant analysis

Corpus callosum		*Predicted Group Membership*			*Total*
		Splenium	*Trunk*	*Genu*	
%	*Splenium*	*100.0*	*0.0*	*0.0*	*100.0*
	Trunk	*5.9*	*76.5*	*17.6*	*100.0*
	Genu	*3.0*	*0.0*	*97.0*	*100.0*

96.2% of original grouped cases correctly classified

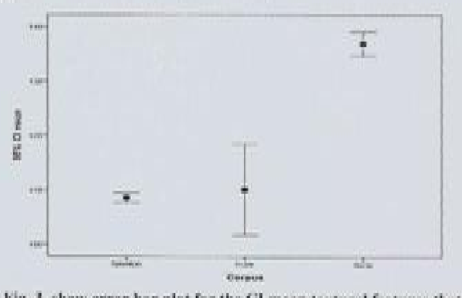


Fig. 3. show error bar plot for the CI mean textural features that selected by the linear stepwise discriminate function as a discriminate feature where it discriminates between all features. From the discriminate power point of view in respect to the applied features the mean can differentiate between all the classes successfully

Table (1) show classification score matrix generated by linear discriminate analysis and the overall classification accuracy of corpus collosum parts 96.2%, were the classification accuracy

;

of Splenium 100.0 %, Trunk accuracy 76.5 %, While the Genu showed a classification accuracy 97.0%.

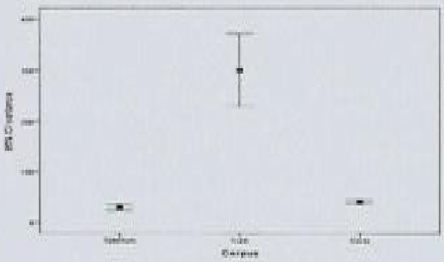


Fig. 4. Show error bar plot for the CI variance textural features that selected by the linear stepwise discriminate function where it discriminates between all features

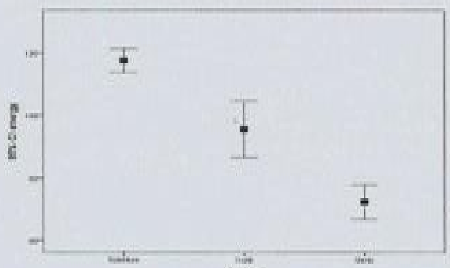


Fig. 5. Show error bar plot for the CI energy textural features that selected by the linear stepwise discriminate function where it discriminates between all features

Conclusion

Characterize the corpus collosum parts to splenium, trunk and genu in MR images using first order statistic and extract classification features from MR images. The FOS techniques included eight's features, and carried out using Interactive Data Language (IDL). The result of the classification showed that the corpus collosum areas were classified well from the rest of the tissues. Using first order statistic the features give a classification accuracy of corpus collosum parts for splenium 100.0%, trunk 76.% and the genu classification accuracy 97.0%.

The overall classification accuracy of corpus collosum area 96.2%. From Linear discrimination analysis generated a classification function which can be used to classify other image into the mention classes as using the following multi regression equation

Splenium = (mean× 0.513) + (variance × 0.009) + (energy × 0.022) – 30.397

Trunk = (mean × 0.558) + (variance × 0.07) + (energy × - 0.012) – 41.76

Genu = (mean × 0.725) + (variance × 0.014) + energy × - 0.058) – 48.94

REFERENCES

Atlas, S.W., Zimmerman, R.A., Bilaniuk, L.T., *et al.* Corpus callosum and limbic system: neuroanatomic MR evaluation Of developmental anomalies. *Radiology.* 160:355–362

Barkovich, A.J., Norman, D. 1988. Anomalies of the corpus callosum: correlation with further anomalies of the brain. *Am J Neuroradiol.*, 9:493–501

Barkovich, A.J., Simon, E.M., Walsh, C.A. 2001. Callosal agenesis with cyst: a better understanding and new classification. *Neurology.*, 56:220–227

Barkovich, A.J. 2003. Anomalies of the corpus callosum and cortical malformations. In: Barth PG, ed. *Disorders of Neuronal migration (international review of child neurology).* London, UK: Mac Keith Press, 83–103

Byrd, S., Radkowski, M., Falnnery, A., McLone, D. 1990. The clinical and radiologic evaluation of absence of the corpus callosum. *Eur J Radiol.*, 10:65–73

Davila-Gutierrez, G. 2002. Agenesis and dysgenesis of the corpus callosum. *Semin Pediatr Neurol.*, 9:292–301

Dobyns, W.B. 1996. Absence makes the search grow longer. *Am J Hum Genet.*, 58(1):7–16.

Jeret, J.S., Serur, D., Wisniewski, K., et al. 1985. Frequency of agenesis of the corpus callosum in the developmentally disabled population as determined by computerized tomography. *Pediatr Neurosci.* 12(2):101–3.

Rakic, P., Yakovlev, P.I. 1963. Development of the corpus callosum and cavum septi in man. *J Comp Neurol.* 1968;132(1):45–72. doi: 10.1002/ cne.901320103 [published Online First: Epub Date]].

Wahl, M., Lauterbach-Soon, B., Hattingen, E., et al. 2007. Human motor corpus callosum: topography, somatotopy, and link between microstructure and function. *J Neurosci.*, 27(45):12132–8. doi: 10.1523/JNEUROSCI.232007. 2007[published Online First: Epub Date]].

****