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Sudan University of Science and Technology

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كلية الدراسات العليا

A Study of Cerebrum and Cerebellum Anatomical Dimensions in Sudanese using Magnetic Resonance Imaging (MRI)

دراسة الأبعاد التشريحية للمخ و المخيخ لدى السودانين باستخدام التصوير بالرنين المغناطيسى

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الايه

بسم الله الرحمن الرحيم

قال تعالي :

{ اللَّهُ نُورُ السَّمَاوَاتِ وَالأَرْضِ مَثَلُ نُورِهِ كَمِشْكَاةٍ فِيهَا مِصْبَاحٌ
الْمِصْبَاحُ فِي زُجَاجَةٍ الزُّجَاجَةُ كَأَنَّهَا كَوْكَبٌ دُرِّيٌّ يُوقَدُ مِن
شَجَرَةٍ مُّبَارَكَةٍ زَيْتُونَةٍ لّا شَرْقِيَّةٍ وَلا غَرْبِيَّةٍ يَكَادُ زَيْتُهَا يُضِيءُ وَلَوْ
لَمْ تَمْسَسْهُ نَارٌ نُّورٌ عَلَى نُورٍ يَهْدِي اللَّهُ لِنُورِهِ مَن يَشَاء وَيَضْرِبُ
اللَّهُ الأَمْثَالَ لِلنَّاسِ وَاللَّهُ بِكُلِّ شَيْءٍ عَلِيمٌ } (35) **سورة النور**

صدق الله العظيم

Dedication

To my lovely parents ....

Whom the first reasons of my life and from them take the hope scintillation light for continues

TO my small warm family...my dear husband& kids........

Whom support and encourage me

TO my beloved brothers...

With all love

For them all I dedicate this effort with all hope to be as they expect me

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First, the greatest thanks to God almighty Allah for all blessedness and for completing all my starts and actualizes all my dreams alhamdlelah

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Abstract

This cross sectional descriptive study was done to measure the cerebrum and cerebellum structures. As well it was carried out to establish normal Sudanese reference values for cerebrum and cerebellum dimensions using Magnetic Resonance Imaging (MRI).

The study was done at Yastabshron Medical Center (Omdurman) during period 2014-2018 using MRI machine1.5 Tesla.

All MRI images were obtained with multi scans, axial, sagittal and coronal with FSE, T_2 weighted image and FLAIR techniques.

The sample was divided into two groups: group one was 100 healthy participants 39% were males and 61 % were females, their mean age was 42.36±17.87 years old (Min=14.00, Max=80.00 years).

In group one; linear measurements were taken for Cerebellum and cerebrum, in Axial and coronal scans; length and width for each hemisphere were taken, as well as maximum width and maximum length were also been measured. In Sagittal scan the Anteroposterior (AP) vermin diameter and width were measured.

The study results showed that the cerebrum length was affected by age significantly at p=0.004; however no age related differences were noticed in the cerebellum measurements. The degree of the reduction in the cerebellar measurements is (3-4) mm and unlikely to be significant. Measurements of cerebellum and cerebrum were noticed to be less in females than males, where the cerebellum hemisphere maximum width and cerebrum length were affected significantly by gender, while the cerebellum height and AP vermin width were not significantly correlated with gender.

Group Two was another 100 participants where the Cerebellum volume and vermin area were measured, In this group 41% were males and 59% were females. The mean cerebellum volume was 190.6 cm^3± 21.57. There is no

significant relation between cerebellum volume and age where a significant relation was found with gender and at p=0.000 .The vermin area is greater in males with average 115.4±18.88cm^2 than females with average of 111.1 ±19.73 cm^2 .The study found that there is no significant relation found between vermin area, age and gender.

This study provide a valuable addition to the normative database of the cerebellar and cerebrum anatomy for Sudanese .These data are an attempt to support the norms of the cerebellum data measured in axial and sagittal images. In addition this study showed that Sudanese have a larger cerebellum volume compared with other population.

الخلاصه

أجريت هذة الدراسه التشريحية المقطعية الوصفية لقياسات تركيب المخ والمخيخ ؛ لإنشاء مرجعية لقياسات السودانين عن طريق إستخدام الرنين المغنطيسي، فى مركز يستبشرون الطبى فرع أمدرمان في الفترة مابين 2018-2014 .أستخدمت ماكينة رنين مغنطيسي بقوة 1.5 تسلا . أخذت جميع صور الرنين بمختلف الأوضاع المسحيه بالبرتوكل الأساسي لمسح المخ ، بوضعيات أ مامية خلفية وجانبية ومحورية .

أجريت هذة الدراسه بعينة تحتوى على 200 مشارك بفئات عمر بين(80-14) سنه، قسمت لمجموعتين متساويتين ، المجموعة الأولى تحتوى على 61% منهم إناث و39% منهم ذكور بمتوسط عمر87.17±36.46 سنه ،اجريت لهذة المجموعة الأولى القياسات الخطية للمخ والمخيخ ، حيث تم قياس طول وعرض المخيخ كقياس أ قصى و أدنى للمقطع المحورى والامامى الخلفى ، قياساً عاماً للمخ والمخيخ ولفصيهما الأ يمن والأيسر كل على حدة، أما للمقطع الجانبي فتم قياس الارتفاع والعرض للمنطقه الوسطى للمخيخ .

وجدت الدراسة ان طول المخ يتاثر بدرجة كبير بالنسبه للعمر بقيمة معنوية .0004 امابالنسبة للمخيخ لم يكن هناك تغير ملحوظ لقياسات المخيخ مع العمر ؛فدرجه تغيرة وإضمحلاله متوسطه وغير معنوية ، اما بالنسبة لتاثير القياسات بالنسبة للنوع فكانت قياسات المخ والمخيخ بالنسبة للإناث اقل من الذكور والقياسات القصوى كان لها تاثير واضح بالنسبه للنوع يعزى لصالح الذكور دون الإناث.

أما المجموعة الثانية تحتوى على 100مشارك آخر فية 41%ذكور 59%إناث ا ُجريت لهم قياسات الحجم بالنسبة للمخيخ وقياس مساحه المنطقة الوسطى له فوجد متوسط حجم المخيخ 190.6 ± 21.57 سم ٣

وأعلى قيمه له هى 193± ٢. 24.18 سم٣ فى الفئة العمرية (63 -47) سنة .

كما وجد الدراسة أنه ليس هناك تاثير معنوى بين حجم المخيخ والعمر بينما هناك تاثير معنوى كبير لصالح الذكور من الإناث بالنسبة للنوع بقيمة معنوية٠٠٠. ٠ أما المنطقة الوسطى للمخيخ كانت اقل قيمة لها 13.93±108.6 سم٢ فى الفئة العمرية بين (46-31) سنة وأعلى قيمة لها كانت 17.14±121.5 سم ٢ فى الفئة العمرية بين (64-80) سنة،كما وجد انه لها أكبر قراءه فى الذكور مقارنة بالإناث ، بمتوسط للذكور 18.88± 115.4 سم٢ اما للإناث 19.73±111.1ذسم ٢، وجدت الدراسة ان المنطقه الوسطى لها تاثر معنوى بالنسبه للعمر والنوع.

هذة الدراسة أضافت قيم مرجعية تشريحية طبيعية بالنسبة للمخ والمخيخ ، كما أنها محاوله لإيجاد القيم المرجعيه لقياسات للمخ والمخيخ فى المقاطع المحورية والجانبيه لمسح الرنين المغنطيسى ،كما ان قياسات الخ والمخيخ القصوى لها تاثر بالنوع ،كما ان حجم المخيخ لدى السودانين أ كبر مقارنه بالشعوب الأخرى.

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Glossary of Abbreviations

The abbreviation	The meaning or statement
AICA	Anterior inferior cerebellar artery
ADC	Apparent diffusion coefficient
AP	Antero posterior
C .C	Cephaliccaudly direction
CT	Computer tomography
C.V	Cerebellum volume
CM Line	Canthio metal line
CATK	Cereberaller analysis tool kite
DWI	Diffusion weighted image
DTI	Diffusion tensor image
EMG	Electro myography
fMRI	Functional magnetic resonance imaging
F.S.E	fast Spin echo
F.O.V	Field of view
Flair	Fluid attention at inveration recovery time
GA	General age
GA	Gestational age
GE	General electrical
HU	Hounsfield unite
HZ	Hertz
I.C.V	Inter cranial volume

L.M.P	Last menstruation period
LT	Left
MRI	Magnetic Resonance Imaging
M.S	Multiple sclerosis
MSEC	Milli second
MBq	Mega Becquerel
PACS	Picture archiving and communication system
PICA	Posterior inferior cerebellar artery
PCA	Posterior cerebellar artery
PCF	Posterior cranial fossa
PT	Patient
P.F	Posterior fossa
PET	Positron emission tomography
RT	Right
ROI	Region of interest
RCBF	Regional cerebral blood flow
SD	standard deviation
SCA	Spino cerebellar ataxia
S C A	Superior cerebellar artery
SC	Supra tentoria of cranium
SPSS	Static package of social studies
SPECT	Single piston emission of computer tomography

SE	Spin echo
STIR	Short Time at Ti inveration recovery
TR	Time of repeat ion of RF
TE	Time of echo
TRV	Transvers diameter
TCD	Transvers cerebellum diameter
T	Tesla
U/S	Ultra sound
VAP	Vermeil antro posterior
VBM	Volume brain measurement
VBM	Volume based morphety
VH	Vermeil height
WML	White matter lesion

Chapter One

Introduction

Chapter One

Introduction

1.1Perulde of cerebrum:

The human brain is the central organ of the human nervous system, and with the spinal cord makes up the central nervous system. The brain consists of the cerebrum, the brainstem and the cerebellum. It controls most of the activities of the body, processing, integrating, and coordinating the information it receives from the sense organs, and making decisions as to the instructions sent to the rest of the body. The brain is protected by the skull bones of the head. (Snell, 2018).

The cerebrum is the largest part of the human brain. It is divided into two cerebral hemispheres. The cerebral cortex is an outer layer of grey matter, covering the core of white matter. Each hemisphere is conventionally divided into four lobes the frontal, temporal, parietal, and occipital lobes. The frontal lobe is associated with executive functions including self-control, planning, reasoning, and abstract thought, while the occipital lobe is dedicated to vision. Within each lobe, cortical areas are associated with specific functions, such as the sensory, motor and association regions. Although the left and right hemispheres are broadly similar in shape and function, some functions are associated with one side, such as language in the left and visual-spatial ability in the right. The hemispheres are connected by commissural nerve tracts, the largest being the corpus callosum. (Guyton and Hall, 2018)

The cerebrum is connected by the brainstem to the spinal cord. The brainstem consists of the midbrain, the pons, and the medulla oblongata. Within the cerebrum is the ventricular system, consisting of four interconnected ventricles in which cerebrospinal fluid is produced and circulated.

The brain is protected by the skull, suspended in cerebrospinal fluid, and isolated from the bloodstream by the blood brain barrier. However, the brain is still susceptible to damage, disease, and infection. Damage can be caused by trauma, or a loss of blood supply known as a stroke. (Snell, 2018).

1.2 Prelude of cerebellum:

The cerebellum is very important part in the skull which known as little brain. The cerebellum is a part of the brain which responsible for human movement, coordination, motor control and sensory perception. It lies under the cerebrum, towards the back, behind the brainstem and above it. The cerebellum is look like the brain, it receive the signals from all over the body through the neural pathways to keep the mind aware of where the body is positioned and how response as soon as possible for environmental change to keep our body safely. Persons whose cerebellum doesn't work well are generally clumsy and unsteady. They may look like they are drunk even when they are not. (Nielsen, et al .2016).

The cerebellum is responsible for relaying message about posture ,equilibrium ,movement and fine motor skill such as writing or catching a ball .voluntary movement is monitored and initialized through the manipulated of fine movement ,the injuries of it can lead to form of paralysis in many various way such as paraplegia ,partial impairment of motor neuron pathways (Last , 2016).

The cerebellum is comprised of white matter and a thin, outer layer of densely folded gray matter. The folded outer layer of the cerebellum which called cerebellar cortex has smaller and more compact folds than those of the internal cerebral (Nielsen et al .2016). it consist of two hemispheres united in mid line by portion of cerebellar substance known as the vermis, and two cerebellum hemispheres separated from each other by dura fold called falx cerebella and separated from cerebrum by other dura fold called cerebellum tentorium(Last , 2016).

The cerebellum contains hundreds of millions of neurons for processing data. It relays information between body muscles and areas of the cerebral cortex that are involved in motor control. (Nielsen, et al. 2016).

Several investigators have observed gender related differences in gross cerebellar neuroanatomy. Males were shown to have larger cerebella than female those of same age these differences could have reflected sexual causes dimorphism of body size was not consistently ruled out (Nielsen, et al .2016).

Little matched females, had showed that the possibility of regarding differences in the development of cerebellar compartments, despite their having important characteristics regarding function, anatomical connections with the cortex, and an important role in neurodevelopment disorders as mentioned by Romani in (Romani, 2006).

The awareness of normal neuroanatomic variability is important for understanding any pathologic change. MRI studies have correlated midbrain morphology with symptomatology in several disorders, including Parkinson disease (Huber, et al .1990) and Wilson disease (Matti, 2006) suggesting that morphometric data may indirectly reflect underlying neurochemical or pathologic process. (Coffman, et al. 1989) found no difference between schizophrenics and controls, whereas (Nasrallah, et al.1991) reported that schizophrenics patients have larger cerebellar structures than controls subjects.

However, a number of MRI studies could not confirm the vermeil atrophy in schizophrenic patients (Mathew, et al.1985; Aylward, etal. 1994).

The data on age related changes of the cerebellar vermis in normal subjects will facilitate further investigation of the relation between cerebellar vermis changes and the neuromotor decline with normal aging and in different gender establishing normative data can be used to compare the findings in patients with neurologic disorders ,as well ,this study may support the findings of morph metrical sex differences and age related changes as there are discrepancies in the results concerning the age related to change in cerebellar vermis remain speculative, though some authors suggest a selective vulnerability of specific posterior fossa structures to the effects of aging and sex. (Mathew, et al.1985).

There are many classification in study the cerebellum first one anatomic division and second one called Phylogenetic and functional division. An awareness of normal neuroanatomical variability is important for understanding pathologic changes. In regard to the posterior fossa structures, most of the researches record of in vivo studies are few and there is a need for normative data about the cerebellum. (Nielsen, et al .2016).

To the best of our knowledge, no Sudanese studies were obtained and included Cerebellum volume the most of them focus in brain and sub division of enter canal structural , the some previous study show no significant relation with a age but there are significant consideration with sex which is more larger in male than the female as mentioned by (Escalon, et al .1991;mureshed, et al .2003).Also there is not clear measurements of the same individuals in the axial, and sagittal of MR images as well, In this current prospective study, the examination variable were age and gender.

The cerebellum volumetric measurement provide good chance to discover any abnormality that can be affected the cerebellum and make disturbance in it is function, which lead to imbalance to whole body and make disturbance to all activates , MRI is one of the solution which help in measuring the cerebellum Therefore any problem effect the cerebellum lead to imbalance in the ordinary activates but by radiological investigation offer the possibility of estimation any pathological change that might be occur in future such as dementia ,especially when using the magnetic resonance imaging(MRI).

1.3 General objectives:

-To Study of cerebrum and cerebellum anatomical dimensions in Sudanese population using magnetic resonance imaging (MRI).

1.3.1 Specific Objectives:

- To evaluate the linear cerebellum maximum measurements in axial, coronal and sagittal planes.

- To evaluate the linear cerebrum maximum measurements in axial and coronal planes

-To evaluate the length and width measurements of right and left cerebellum and cerebrum hemispheres in axial and coronal scan.

-To calculate the vermin height, width measurements in sagittal plane and the relation with age.

-To correlate the cerebellum volume and vermin areas with gender and age.

-To correlate the cerebellum hemispheres (length-width) with brain measurements in different scan planes.

- To correlate the right cerebellum hemisphere with right cerebrum hemisphere.

- To correlate the left cerebellum hemisphere with left cerebrum hemisphere.

- To establish the norms reference for Sudanese cerebellum volume.

-To compare the Sudanese cerebellum volume with other population

1.4 Problem of the Study:

There is no literature and back ground reference to cerebellum linear measurements , volume and vermeil area in Sudan, many population have stander cerebellum measurement consider as normative data, and to the best of our knowledge ,no published cerebellum norms have been reported in the open literature and no measurements or index value for the Sudanese were established .The question to be answered : What are the standard measurements of the cerebellum and cerebrum for Sudanese subjects in different age groups and gender , can MRI able to detect the measurement of cerebellum and cerebrum in all planes is impact of the age and gender on cerebellum volume and vermeil area of the Sudanese subjects

1.5 Thesis over view :

This study contain five chapters:

Chapter one: deal with introduction

Chapter two: theoretical back ground &previous literature review

chapter three: material &method.

Chapter four: data analysis &result

Chapter five: discussion , conclusion and recommendations

Chapter Two

Literature Review

Chapter Two

Theoretical Back Ground & Literature Review

2.1 Anatomy of cerebrum:

The cerebrum is the largest part of the brain, and is divided into nearly symmetrical left and right hemispheres by a deep groove called the longitudinal fissure . The hemispheres are connected by five commissure that span the longitudinal fissure, the largest of these is the corpus callosum . Each hemisphere is conventionally divided into four main lobes; the frontal lobe, parietal lobe, temporal lobe, and occipital lobe, named according to the skull bones that overlie them .The surface of the brain is folded into ridges (gyri) and grooves (sulci), many of which are named, usually according to their position, such as the frontal gyrus of the frontal lobe or the sulcus separating the central regions of the hemispheres. There are many small variations in the secondary and tertiary folds. (Guyton and Hall, 2018).

The outer part of the cerebrum is the cerebral cortex, made up of grey matter arranged in layers. It is 2 to 4 millimeters (0.079 to 0.157 in) thick, and deeply folded to give a convoluted appearance. Beneath the cortex is the cerebral white matter. The largest part of the cerebral cortex is the neocortex, which has six neuronal layers. The rest of the cortex is of allocortex, which has three or four layers (Guyton and Hall, 2018).

The cortex is mapped by divisions into about fifty different functional areas known as Brodmann's areas. These areas are distinctly different when seen under a microscope. The cortex is divided into two main functional areas a motor cortex and a sensory cortex. The primary motor cortex, which sends axons down to motor neurons in the brainstem (Guyton and Hall, 2018).

The internal carotid arteries supply oxygenated blood to the front of the brain and the vertebral arteries supply blood to the back of the brain. These two circulations join together in the circle of Willis, a ring of connected arteries that lies in the interpeduncular cistern between the midbrain and pons. (Guyton and Hall, 2018).

Cerebral veins drain deoxygenated blood from the brain. The brain has two main networks of veins: an exterior or superficial network, on the surface of the cerebrum that has three branches, and an interior network. These two networks communicate via anastomosing (joining) veins. The veins of the brain drain into larger cavities the dural venous sinuses usually situated between the Dura matter and the covering of the skull. Blood from the cerebellum and midbrain drains into the great cerebral vein. Blood from the medulla and pons of the brainstem have a variable pattern of drainage, either into the spinal veins or into adjacent sinus (Guyton and Hall, 2018).

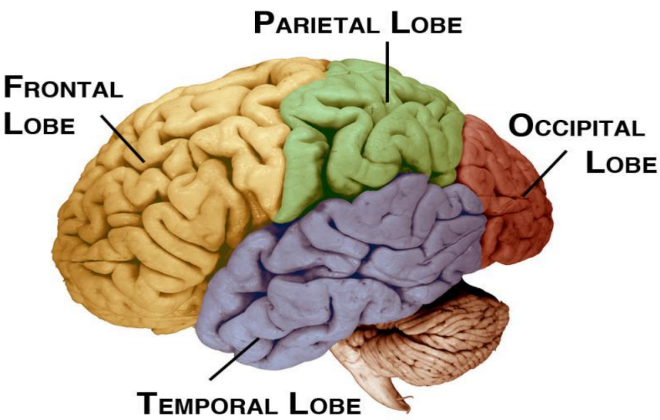


Figure NO (2-1): The cerebrum anatomy

http://www.flanderstoday.eu/innovation/ku-leuven-discovers-brain-process-responsible-gripping

2.2 Anatomy of cerebellum:

2.2.1 Cerebellum location and division:

The cerebellum is located at the bottom of the brain, and occupies the posterior cranial fossa which it lies posterior to brain stem and inferior to occipital lobe of cerebrum, the cerebellum separated from the medulla and pons by fourth ventricle. It consists of two hemispheres united in midline by portion of cerebellar substance known as the vermis and separated by falx cerebella which is fold of dura matter. The cerebellum isolate or separated from cerebrum by other fold of dura matter called tentorium of cerebellum (Lats 2016; Willim 2019; Concine 2014)

There are three peduncles which also connect each hemisphere to brain stem ,the superior one enter the mid brain ,the middle one consist of transverse fiber of pons but the inferior one arise from the medulla(Lats ,2016).

The vermis is lies in medial between two cerebellar hemisphere and more extensively folded and fissured than the cerebral cortex there are 10 primary lobules in the vermis numbered from I-X from superior to inferior ,first one called lingual and anatomical labeled with[I] and lies in superior of the vermis which is contact with superior medullary velum , the second one called centralize which contain two lobules and labeled with [II-III], the third part called the culmen and contain two segment from lobules and labeled with[IV-V],the fourth one called lobus simplex and it separated from the previous one by fissure called primary fissure and labeled with[VI], the fifth one contain two part first one called folium and the second called tuber and the both labeled with[VII] and it separated from the sixth one by fissure called, prepyramidal sulcus and the sixth known with pyramid and labeled with[VIII]the seventh part called uvula and labeled with[IX],but the last part called nodulus and anatomical labeled with[X] .and all this parts of vermeil lobule are arranged from superior to inferior in sagittal section of cerebellum(Schottellius and byvon ,2018)

The vermis is division into two main parts superior and inferior parts, the superior one is median ridge on the superior surface, it lies inferior to the line junction of tentorium cerebelli with falx cerebri.

The inferior verims bulges into a deep median hollow on anterior inferior surface of cerebellum which called the valleecula of the cerebellum, here the vermis is separated from the hemisphere by deep furrows(Roman and Inghme,2018).,the two parts of verims separated from each other by neocerebellar posterior lobe which meet in the midline behind the primary fissure.

On gross inspection, three lobes can be distinguished in the cerebellum the flocculonodular lobe, anterior lobe which lie rostral to the primary fissure and the posterior lobe lie dorsal to the primary fissure. The latter two can be further divided in a midline cerebellar vermis and lateral cerebellar hemispheres (Willim, 2019).

The medio lateral border of posterior lobe of each cerebellar hemispheres form the cerebellar tonsil (Willim, 2019).

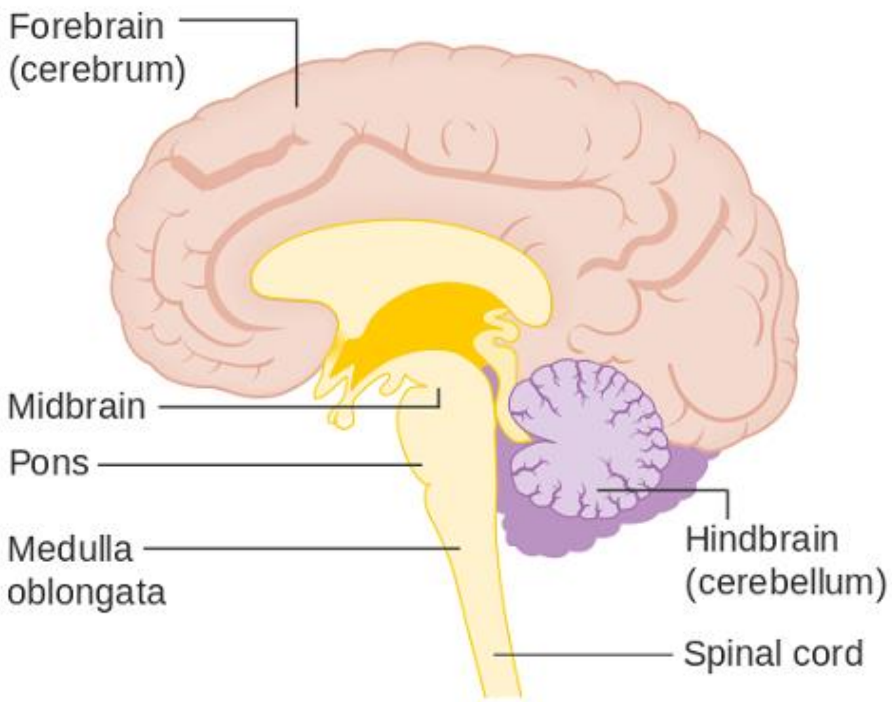


Figure No (2-2): Shows The location of cerebellum and the relation of it with brain parts https://www.google.com/search?q=cerebellum+image&tb

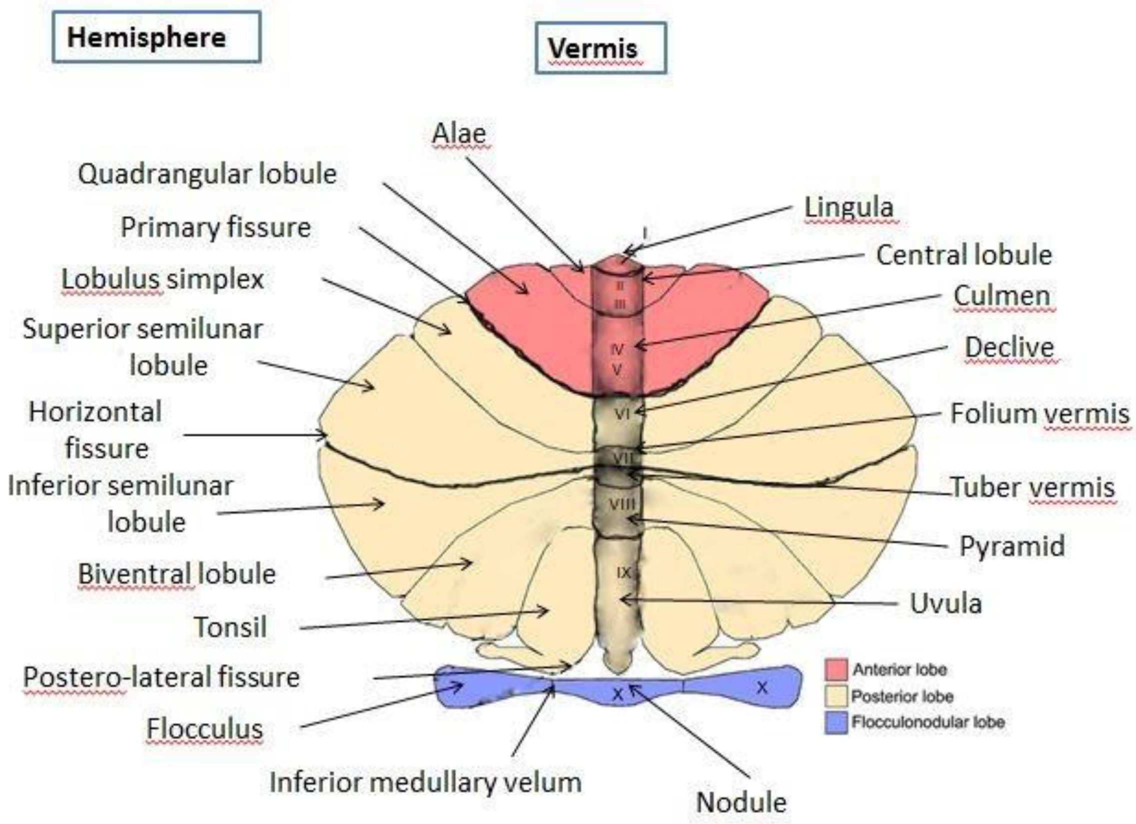


Figure No (2-3):Describe The cerebellum vermis and it is parts and fissures https://www.google.com/search?q=cerebellum+image&tbm=isch&source=univ

2.2.2 Cerebellum surfaces:

There are two surfaces to cerebellum first one is superior surface which is bounded posteriorly by convex border that lies below the attached margin of tentorium cerebella from this border the superior surface slopes concavely upward in conformity with shape of tentorium.

The second one called the postero-inferior surface are boldly convex below the posterior border which known as appropriate name of (nates)which occupies the concavities of the occipital bone and between them there are groove called vallecula(cistern magnacerebelli) which lodges three parts of inferior vermis and it consist from three lobules: pyramids ,uvula and nodule(Lats,2016).

The cerebellum is surface with cortex of grey matter external with white one internally like cerebrum, and the cerebellum is separated from the overlying cerebrum by a layer of leathery dura mater; all of its connections with other parts of the brain travel through the pons. Anatomists classify the cerebellum as part of the mesencephalon, which also includes the pons (James, 2017) the mesencephalon in turn is the upper part of the rhomb encephalon or "hindbrain". The white matter, made up largely of myelinated nerve fibers running to and from the cortex. Embedded within the white matter which is sometimes called the arbor vitae or Tree of Life in the cerebellum (Lats, 2016) the cerebellar tentorium is Dura partition which form the roof of posterior fossa and separating the cerebellum from overlying of tempers – occipital lobe of cerebellum

The cerebellum formed from three fissure:

- Fissure prima: it is deepest fissure separate the anterior and posterior lobe (Romanes and Inghmes, 2018).
- Horizontal fissure: extend from middle cerebellum pendule to other and lies close the junction of superior and inferior surface (Romanes and Inghmes, 2018).
- postro lateral fissure: it lies on anteroinferior surface of cerebellum and separated the nodule and floccules from remainder of cerebellum (Romanes Inghmes, 2018).

The cerebellum also contain two paired deep nuclei and three paired peduncles the dentate nuclus is large one which open in superior peduncle which is important one because is main connexions from neocerebellum, also there are three lie masses of nucli lie in dentate called emboliformis, globosus and fatigii and there are known as roof nucli but the peduncles are three also superior, middle and inferior one (Last, 2016). The second one called vestibular nuclei or deiter in addition, these nuclei receive both inhibitory and excitatory signals from other parts of the brain which in turn affect the nucleus's outgoing signals (Snell 2018; Romances and Inghmes, 2018)

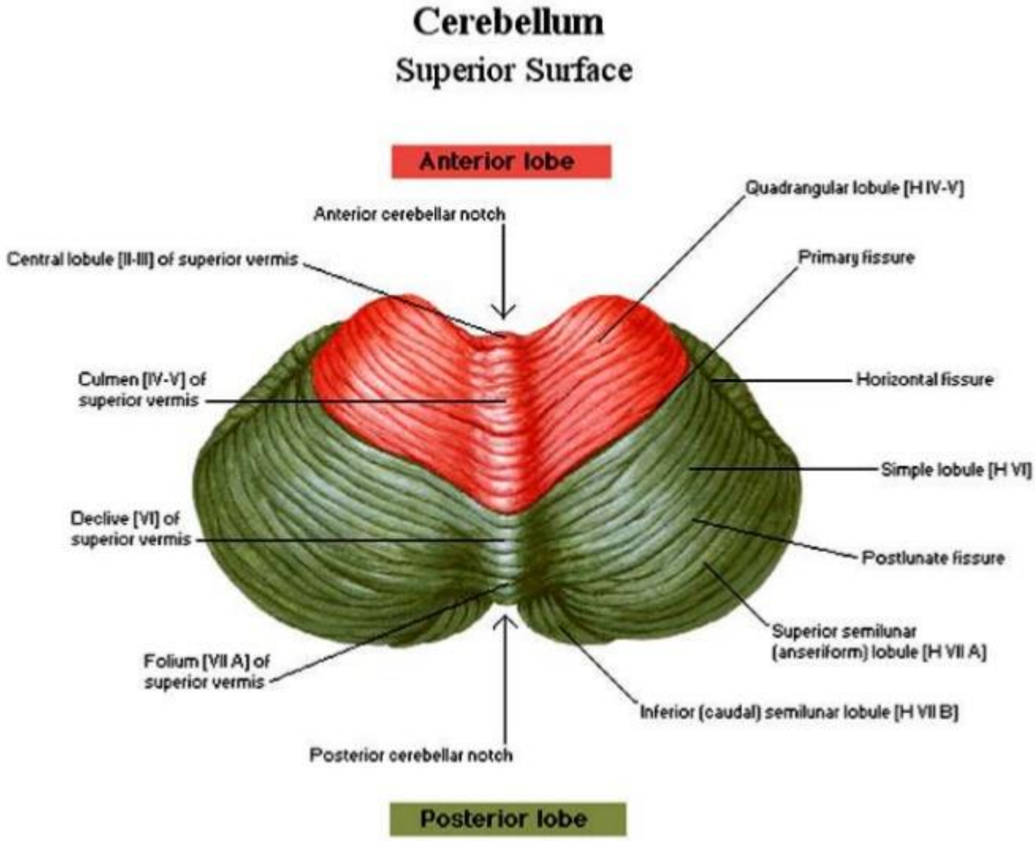


Figure No (2-4): Describe The anterior view of cerebellumhttps://www.google.com/search?q=cerebellum+image&tbm=isch &source

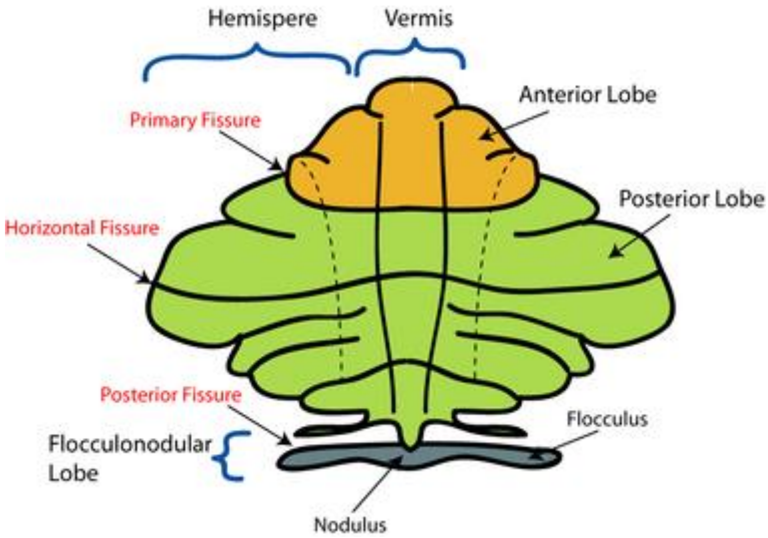


Figure No (2-5): Describe Schematic representation of the major anatomical subdivisions of the cerebellum. Superior view of cerebellum, placing the vermis in one plane in anterior aspect.

https://en.wikipedia.org/wiki/Cerebellum#/media/File:CerebellumDiv.png

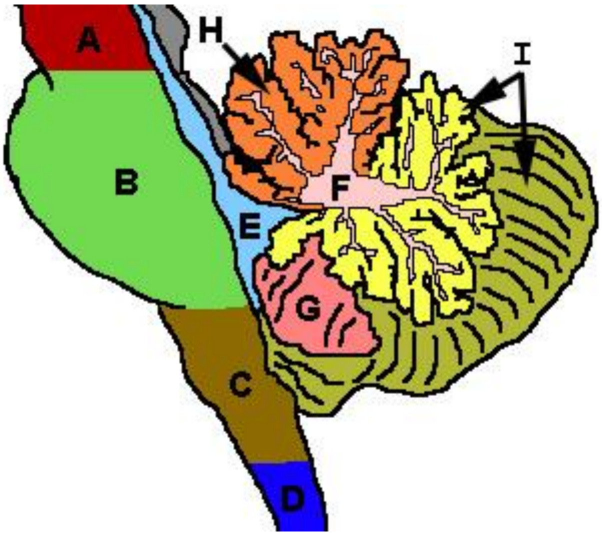


Figure No (2-6): ShowS Cerebellum and surrounding regions; sagittal view of one hemisphere. A: Midbrain. B: Pons. C: Medulla. D: Spinal cord. E: Fourth ventricl

https://en.wikipedia.org/wiki/Cerebellum#/media/File:CerebellumDiv.pnge

2.2.3 The microscopic anatomy of cerebellum:

In the microscopic study the cerebellum divided into three layers cortical, granular and Purkinje and three cells Purkinje cell, basket cells and granule cells and there are:

2.2.3.1 Cortical layers:

There are three layers to the cerebellar cortex; from outer to inner layer, these are the molecular, Purkinje, and granular layers. The function of the cerebellar cortex is essentially to modulate information flowing through the deep nuclei. The micro circuitry of the cerebellum is schematized in Figure below which explain the Mossy and climbing fibers carry sensorimotor information into the deep nuclei, which in turn pass it on to various premotor areas, thus regulating the gain and timing of motor actions.(Last 2016 ;Willim2019).

Cortical layers

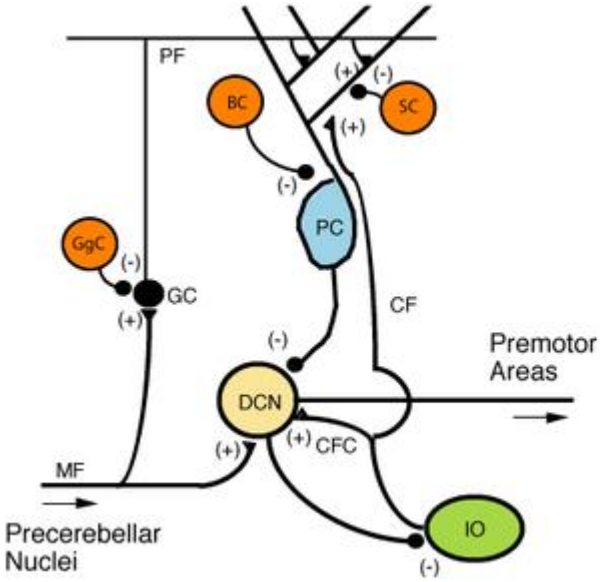


Figure No (2-7): Show The Microcircuitry of the cerebellum. Excitatory synapses are denoted by (+) and inhibitory synapses by (-). MF: Mossy fiber. DCN: Deep cerebellar nuclei. IO: Inferior olive https://en.wikipedia.org/wiki/Cerebellum#/media/File:CerebellumDiv.png

2.2.3.1.1 Molecular layer:

This outermost layer of the cerebellar cortex contains two types of inhibitory interneurons: the stellate and basket cells. It also contains the dendritic arbors of Purkinje neurons and parallel fiber tracts from the granule cells. Both stellate and basket cells form inhibitory synapses onto Purkinje cell dendrites (Last 2016; Willim2019).

2.2.3.1.2 Purkinje layer:

The middle layer contains only one type of cell body that of the large Purkinje cell. Purkinje cells are the primary integrative neurons of the cerebellar cortex and provide its sole output. Purkinje cell dendrites are large arbors with hundreds of spiny branches reaching up into the molecular layer. These dendritic arbors are flat nearly all of them lie in planes with neighboring Purkinje arbors in parallel planes. Each parallel fiber from the granule cells runs orthogonally through these arbors, like a wire passing through many layers. (All or nothing, amplitude invariant) spiking of the Purkinje cell. (Last 2016; Willim2019).

Just underneath the Purkinje layer are the Lugaro cells whose very long dendrites travel along the boundary between the Purkinje and the granular layers. (Last 2016; Willim2019).

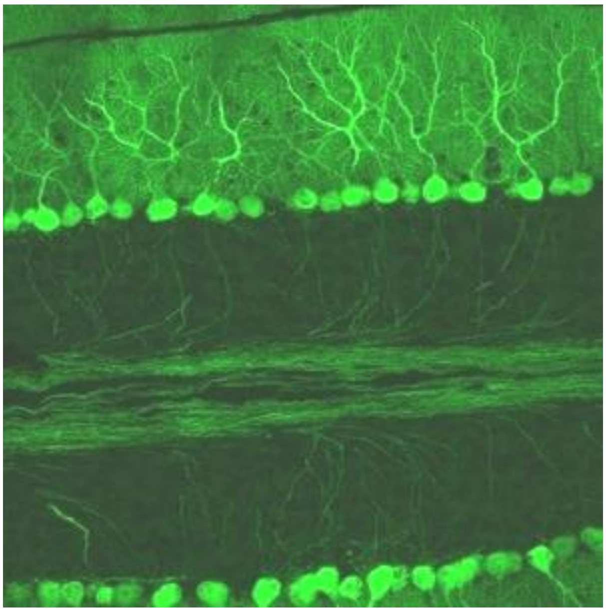


Figure No (2-8): Show The Confocalmicrograph from mouse cerebellum expressing green-fluorescent protein in Purkinje cel
https://en.wikipedia.org/wiki/Cerebellum#/media/File:CerebellumDiv.pngls

2.2.3.1.3 Granular layer:

The innermost layer contains the cell bodies of three types of cells: the numerous and tiny granule cells, the slightly larger unipolar brush cells and the much larger Golgi cells. Mossy fibers enter the granular layer from their main point of origin, the pontine nuclei. These fibers form excitatory synapses with the granule cells and the cells of the deep cerebellar nuclei. The granule cells send their T-shaped axons known as parallel fibers up into the superficial molecular layer, where they form hundreds of thousands of synapses with Purkinje cell dendrites

Table2-1 Describe five neuron type in cerebellar cortex and the distribution in the cerebellar cortical layer (Willim, 2019):

No	Type of neuron	The layer
1	Other stellate	molecular
2	Inner stellate(basket)	molecular
3	Purkinje	purkinje
4	Golgi type ii(Golgi stellate)	granular
5	Granule	granular

2.2.3.2 The glomular of cerebellar :

The cerebellar glomerulus is a small, intertwined mass of nerve fiber terminals in the granular layer of the cerebellar cortex. It consists of post-synaptic granule cell dendrites and pre-synaptic Golgi cell axon terminals surrounding the pre-synaptic terminals of mossy fibers. (Clauvla Kreb etal2011) the function of cerebellar glomeruli are the first processing station for afferent nerve fibers entering the cerebellum. Input comes from the mossy fibers, which terminate there and synapse with the Golgi and granule cell fibers. The Golgi cells regulate the glomeruli with inhibitory signals, and contain executory one .(Dexshutter and Erik ,2002) .Velate astrocytes are glia that sheath the glomeruli which supportelectrophysiological insulation, and chemical equilibrium maintenance in the interstitial fluid, while creating a chemical barrier creating a chemical barrier to the further outgrowth of granule and Golgi cell fibers.(Dexshutter and Erik ,2002) .

2.2.4 The Phylogenetic and functional divisions:

The cerebellum can also be divided in three parts based on both phylogenetic criteria (the evolutionary age of each part) and on functional criteria the incoming and outgoing connections of each part has the role played in normal cerebellar function. From the Functional denomination phylogenetic denomination division to:

- Vestibulocerebellum or Archicerebellum which found and lie on Flocculonodular lobe and immediately adjacent vermis.
- Spinocerebellum(Paleocerebellum)

Which found and lie on verims and intermediate parts of the hemispheres paravermis"

- Cerebrocerebellum (Neocerebellum, Pontocerebellum) Which found and lie on Lateral parts of the hemispheres

Table 2-2 Describe the cerebellum path way or tract (Willim,2019):

N0	Lobar subdvision	Functional subdvision	Afferent peduncle	efferent peduncle	Midline nucleus	Olivary nucleus (medulla)
1	Flocculonodular lobe	Vestibulocerebellum	Caudal	Caudal	Fastigil	Medial accessory
2	Anterior lobe of cerebella	**Spinocerebellum** (Pale-ocerebellum	Rostrol and caudal	rostrol	interpositus	Dorsal accessory
3	Posterior lobe	Cerebrocerebellum	Middle	Rostal	denate	inferior

2.2.5. The Blood supply of cerebellum:

2.2.5.1 The arterial supply:

Three arteries supply blood to the cerebellum First one the superior cerebellar artery (SCA), anterior inferior cerebellar artery (AICA), and posterior inferior cerebellar artery (PICA).

The SCA branches of the lateral portion of the basilar artery, just inferior to its bifurcation into the posterior cerebral artery. Here, it wraps posteriorly around the pons, to which it also supplies blood before reaching the cerebellum. The SCA supplies blood to most of the cerebellar cortex, the cerebellar nuclei, and the superior cerebellar peduncles. (Last, 2016),

The AICA branches of the lateral portion of the basilar artery, just superior to the junction of the vertebral arteries. From its origin, it branches along the inferior portion of the pons at the cerebellopontine angle before reaching the cerebellum. This artery supplies blood to the anterior portion of the inferior cerebellum, the middle cerebellar peduncle, and to the facial (CN VII) and vestibulocochlear nerves (CN VIII). Moreover, it could cause an infarct of the cerebello pontine angle (Last, 2016), the PICA branches of the lateral portion of the vertebral arteries just inferior to their junction with the basilar artery. Before reaching the inferior surface of the cerebellum, the PICA sends branches into the medulla, supplying blood to several cranial nerve nuclei. In the cerebellum, the PICA supplies blood to the posterior inferior portion of the cerebellum, the inferior cerebellar peduncle, the nucleus ambiguous`, the vagus motor nucleus, the spinal trigeminal nucleus, the solitary nucleus, and the vestibulocochlear(Last, 2016).

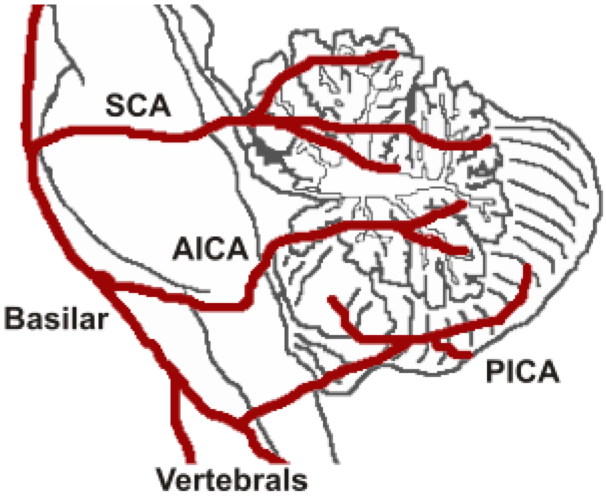


Figure No (2-9): Show The blood supply of cerebellum sagittal view ,The three major arteries of the cerebellum: the SCA, AICA, and PICA https://en.wikipedia.org/wiki/Cerebellum#/media/File:CerebellumDiv.png

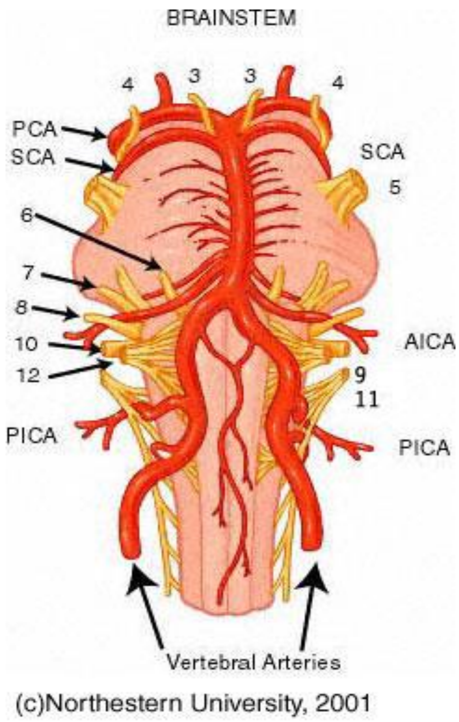


Figure No (2-10): Describe The blood supply of cerebellum anteriorly http//dizzy- doctor.com/thim onyc.chain

There are three main arteries that supply the cerebellum the SCA (superior cerebellar artery), the AICA (Anterior inferior cerebellar artery), and PICA (posterior inferior cerebellar artery)

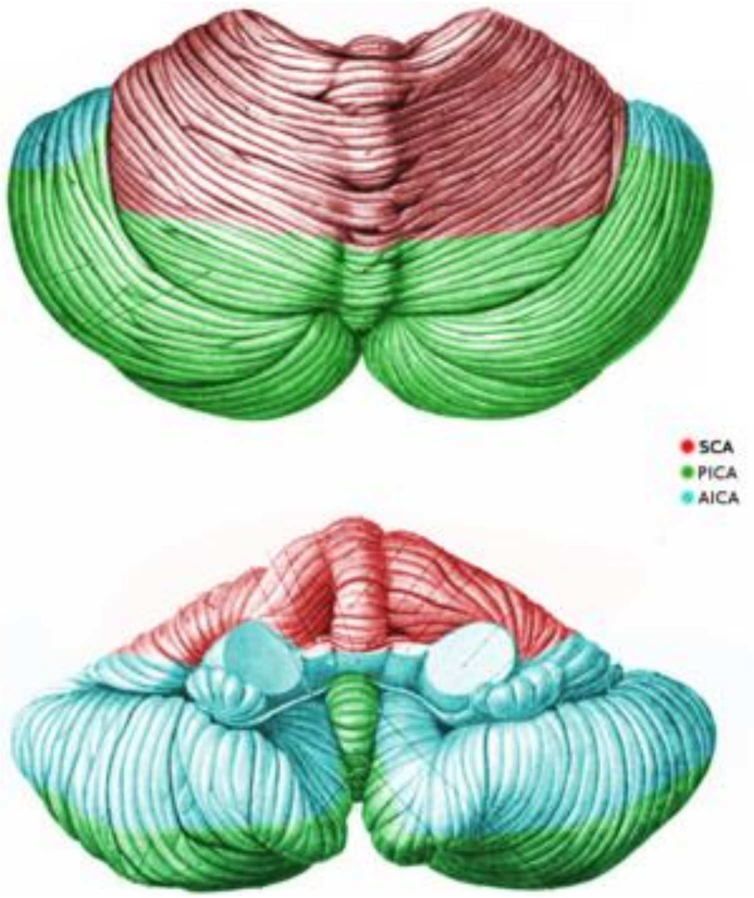


Figure No(2-11): Shows The regions supplied by the three cerebellar arteries.

https://en.wikipedia.org/wiki/Cerebellum#/media/File:CerebellumDiv.png

Three arteries supply blood to the cerebellum the superior cerebellar artery (SCA), anterior inferior cerebellar artery (AICA), and posterior inferior cerebellar artery (PICA).

2.2.5.2 The venous drainage:

The venous drainage start from the surface of cerebellum into the nearest available venous sinus of Dura matter of the brain .thus the superior and inferior surface into the straight and transverse sinus but the inferior surface drain into inferior petrosal ,sigmoid and occipital sinus .the superior vermis drains anteriorly into vein at it is entrance into straight sinus.(Last,2016).

2.3 physiology of the cerebellum:

The cerebellum play important role in all our body activities because it control in our movement , balance ,coordination and equilibrium, and it is like cerebrum consist from two hemisphere which is joined by superior ,middle and inferior peduncle and therefore physiological division into three parts which known as anatomical functional areas of cerebellum and there are **:**

- Archi-cerebellum(older part).
- paleo cerebellum.
- Neo cerebellum (newer part).

The Archi and paleo cerebellum having the function of tone posture and equilibrium but the Neo cerebellum having the function of coordination of our daily activities such as writing ,speaking and walking(Concine ,2014).

2.3.1. function of neo cerebellum:

- Taxia is a condition that involves of coordination between movements of body parts. The term is often used in referelnce to gait or movement of a specific body part, as in “ataxic arm movements” (coordination movement)(Concine,2014).
- Sthemia (movement of muscle) (Concine,2014).
- speech (movement of speech muscle with all skill relation to it include rate and force of voice and movement all muscle enter in this as skills))(Concine,2014).
- Gait(movement in steady and balance mode or way (Concine,2014).
- cognitive(it is consequence of movement) (Concine,2014).

- postural reflexes it is function of anterior lobe which increase the stretch or tendon reflex and cause spastic contraction of muscle(Schottellius and Byvon,2018).
- synergic function :is synchronous and elderly activities of group of muscle called synergies' and related to posterior lobe and affected with it if their lesion in it(Concine,2014).

2.3.1.1Sometime occur dys function in neo cerebellum part and appear as following:

2.3.1.1.1 Ataxia. : occur when the daily coordination movement be Difficult and this can be tested by A\ heel and knee test B\ finger nose test (Consine, 2014).

2.3.1.1 .2 Asthemia: that occur when the muscle became easily fatigue while doing the work. (Consine,2014).

2.3.1.1.3 speech: can be defective when the person could not able to speak quickly as before. (Consine, 2014).

2.3.1.1.4 Gait :while be defective when the person movement be zig zag and fall in one side then stand and walk then fall on the other side (Consine,2014).

2.3.1.2 Function of paleo cerebellum:

- Tone (if occur problem be defective).
- Posture (if occur problem be defective)
- Equilibrium (if occur problem be defective).
- Static. (If occur problem be tremor).
- Nystagmus (eye sign).
- kneejerk. (If occur problem be defective (Consine, 2014).

2.3 .2 The connection of neuron in cerebellum:

There are three cortical cerebellum structures spread in cortical layers which play pig role in enervation the first none is purkinje cell which is a large neuron branched in molecular layer ,but the major cell in this layer is a basket cell ,in the granular layer the granular cell(Schottelius and Byvon ,2018).

The cerebellum have anatomic functional lobe which control in movement and therefore the enervation (excite or inhabit) path through them, but in vermeil area it control in axial movement of the body (Guyton and Hall, 2o18).

There are two type of axons enter to cerebellar cortex the first one called the climbing fiber run through the granular layer and end on the molecular layer on denteries of purkinje cell the second type called the mossy fiber which terminate on the granular cell and both of them consider as two inputs signals of cerebellum but the output responsible from the purkinje axon but during the activity there are two complex action excite and habit(Guyton and Hall 2018; Schottelius and Byvon , 2018).

Table 2-3 Type of cerebellum neurons and their distribution connection (Willim, 2019):

no	Neuron type	Afferent connection	Axonal distrbution
1	Other stellate	Receive fiber from granule neuron	To purkinje neuron
2	Inner stellate(basket)	Climbing fiber	Purkinje via basketcell
3	purkinje	Climbing → from extra cerebellar Paralla fiber → from granula cortex Basket fiber → inner neuron stellate Axon → outer sallate neuron	Most purkinje run to deep nuclei few from them start in flocuonodular then to deep then to vestbular nulei also send to gogli ii
4	Golgi type ii(golgi stellate)	Mossy+ climbing from granular+ molecular	Send to mossy fiber
5	granule	Mossy fiber → fromcerebellar granular	Send fiber to → purkinje ↘ molecular

2.4 Pathology of the cerebellum:

2.4. 1 Diagnosis of Cerebellar disorders:

The cerebellum is largely involved in "coordination". Persons whose cerebellum doesn't work well are generally clumsy and unsteady. They may look like they are drunk even when they are not, which is also include the skill movement such as typing, speech(Thimonync,etal.2017) .

Cerebellar disorders are rare, the prevalence of childhood ataxia is 26/100,000 children. It is rare compared to cerebral palsy and autism In general, prevalence of genetic disorders and especially autosomal recessive disorders is much higher in populations where there is more consanguinity (Thimonync, etal.2017).

The main clinical features of cerebellar disorders include in coordination, imbalance, and troubles with stabilizing eye movements. There are two distinguishable cerebellar syndromes midline and hemispheric (Guyton and Hall, 2018).

There are many medical terminology of cerebellum disease syndrome and sign which describe the pathology of cerebellum lesion and there are:

- Ataxia: means defect in coordination due to error in rate, range, force and direction of movement (Schottelius and Byvon, 2018).
- dys metria : which called past pointing promptly to imitated gross corrective action but the correction over shot to other side is an inability to make a movement of the appropriate distance. Hypometria is undershooting a target, and hypermetria is overshooting a target. Patients with cerebellar damage tend to make hypermetric movements when they move rapidly and hypo metric movements when they move more slowly and wish to be accurate. (Schottelius and Byvon, 2018).
- Iententiontremor: it is absent of rest it appear when patient attempt to perform voluntary action (Schottelius and Byvon, 2018).
- Rebound phenomena: is inability to stop movement promptly Schottelius and Byvon,2018).

- Dyes diadchokinesia: is inability to perform rapidly alternating opposite movement or also called failure to progression or also known as the irregular performance of rapid alternating movements. Intention tremors may be present on an attempt to touch an object (Willim2019; Guyton and Hall 2018; Schottelius and Byvon, 2018).
- Decomposition of movement: difficult to performing action of simultaneous motion at more than one joint at same time Schottelius and Byvon, 2018).
- dysarthria: failure to progression occur during the talking in formation the word(Guyton and Hall, 2018)cerebellar nystagmus : Tremor of eye to balls that occur when try to fixate the eye in one side of the head ,it occur when the flocuo-nodular lobe are damage and associated with lose of equilibrium.
- Hypotonia: The physiological change of hypotonia after cerebellar lesion unclear is an abnormally decreased muscle tone. It is manifest as a decreased resistance to passive movement, so that a limb swings freely upon external perturbation. Hypotonia often limited to the acute phase of cerebellar disease. (Willim , 2019)

2.4.2 The cerebellum diseases:

Cerebellar disorders typically manifest with ataxia incoordination of movement, instability of gait, impairment of articulation, and difficulty with eye movement and swallowing. It has become apparent recently that many cerebellar patients also experience changes in intellect and mood (Schmann, etal. 2004),the cerebellar disorder general divided to congenial and acquired such as Arnold-chiari malformation and cereberallities respectively but due to pathogenic causes it division in to:

- ❖ Inherited or idiopathic degeneration
- ❖ Nutrition Disorders
- ❖ Neoplastic and para neoplastic disorder

- ❖ Developmental Disorders
- ❖ Disorders due to infection
- ❖ Vascular disorder
- ❖ Intoxications Disorders
- ❖ Physical or mechanical trauma
- ❖ Metabolic Disorders
- ❖ Demyelinating Or dyesemyelinating Disorders(Fredericks, etal .2012)

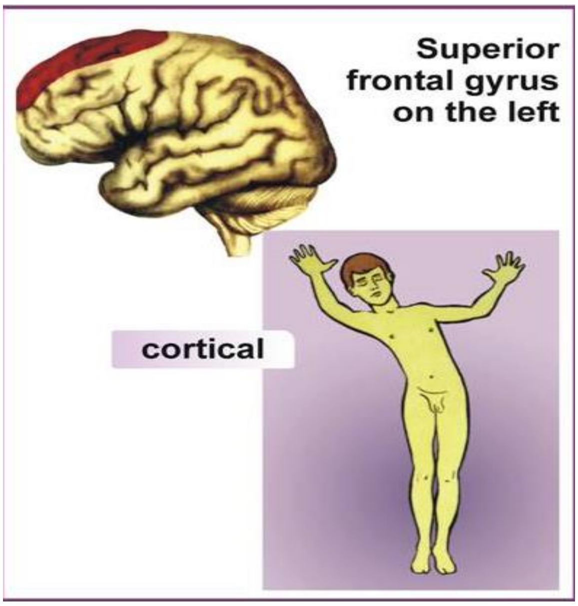
The cerebellum responsible for The smoothly integrated coordination of movements. It is need for movements synergistic contraction of multiple Muscle groups, and it permits such movements to be carried out efficiently And accurately. Incoordination or clumsiness of movement known as atxia and may be involve movement of limb , eye ,speech and gait (Fredericks, etal .2012)

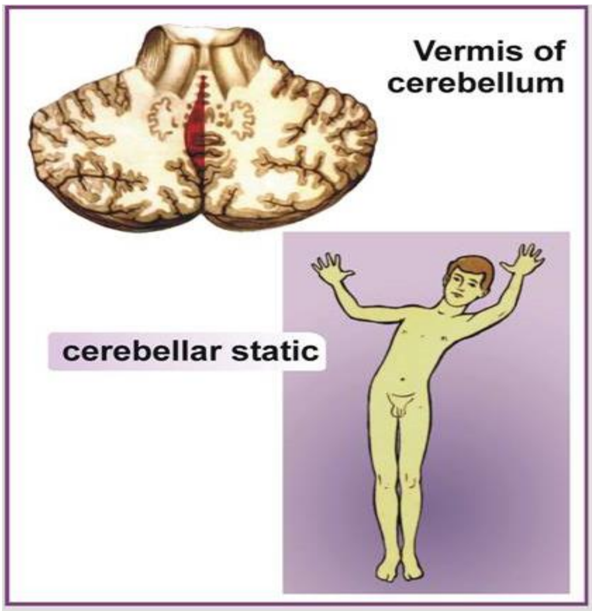
2.4.2 .1 Inherited or Idiopathic Degeneration:

For un known reason ,certain region of central nervous system is particular vulnerable to degenerative disease many of this diseases is genetic or for un known etiology Friedreich's ataxia is the most common example for it. It represent more than50% of this disease it most common in childhood in age between 8-15 years old , it start to affect the lower limb firstly and may be a combine with scoliosis due to affect the spine there are usually weakness and lose of tendons reflex (Fredericks, etal .2012)

Many human inherited neurodegenerative disorders are characterized by loss of balance due to cerebellar Purkinje cell (PC) degeneration. Although the disease causing mutations have been identified for a number of these disorders, the normal functions of the proteins involved remain, in many cases, unknown. To gain insight into the function of proteins involved in PC degeneration, we developed an interaction network for 54 proteins involved ataxia(lim, etal.2006).

Figure No (2-12): Show the Section of spinal cord stained to demonstrate classic lesions in the dorsal columns and spinocerbellar tracts in Friedreich Ataxia. http://neuropathology-web.org/chapter9/images9/9-FRDA.jpg





A B

Figure No (2-13): Describe Different ataxia with different cause http://intranet.tdmu.edu.ua/data/kafedra/internal/nervous_desease/classes_stud/en/med/lik/ptn/neurology/4/02.%20EPS.%20Cerebellum.%20Sensation.htm

figure No(2- 14):ShowsThe MRI in Friedreich ataxia. An 18-year-old woman with cervical cord atrophy and minimal cerebellar atrophy. https://www.semanticscholar.org/paper/Clinical-neurogenetics%3A-friedreich-ataxia

2.4.2 .2Nutrition Disorders:

Adequate nutrition is for both normal development and ongoing functioning of the entire nervous system . nutrition Disorders is particular certain vitamins deficiencies, which affect both peripheral and central nervous system which reflex in mental situation(coma, mental retardation, psychosis) which lead to disturbance of peripheral motor sensory , that defines include vitamins B1 (Thiamine) ,B12 (Cobalamin) and E vitamin. The first one association with alcoholism occur due to also may seen in patient with abnormal gastro intestinal tract , and make syndrome called Wernicke-Korsakoff, but in second vitamin occur due to inability to absorb it and that effect in spine first then in peripheral sensory pathway and the most common is degeneration of spinocerebellar tract, the deficiency of it lead to loss of mylineatd shealth of purkijine cell which lead to loss of white matter volume but the E vitamin deficiencies occur in the adult and same neurological symptoms occur in patient have problem to bile salt absorption . (Fredericks, etal .2012)

2.4.2 .3 Neoplastic and para neoplastic disorder :

Either occur in cerebellum or para it and the most common is carcinoma which affect the cerebellum and combine with encephalopathy, the first thing of sign ataxia in peripheral movement dysarthria and eye movement and in later occur vertigo and patient. complain from diplopia , but in para neoplastic occur due to degeneration of the cerebellar cortex, the sever of it lead to loss of purkijine cell without evidence of inflammation ,this disorder is unclear causes may attributed to nutrition deficiency, it association with lung, breast ,ovaries cancer or Hodgkin's disease and almost patient age over 40 years old whom sever from cerebellum degeneration have para neoplastic disease (Fredericks, etal .2012)

There are a large number of tumors that can either metastasize to the cerebellum such as lung or breast cancer, or arise in the cerebellum itself such as cerebellar astrocytoma or medulloblastoma). The medulloblastoma arises in the cerebellar nodules, and because of this critical location, often presents with dizziness in addition to hydrocephalus. (Thimonync, etal.2017).

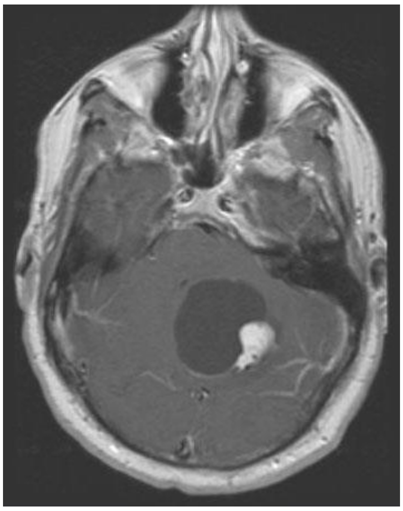


Figure No (2-15):ShowsThe Cerebellar hemangioblastoma with hydrocephalus. (MRI image).

http//dizzy- doctor.com/thimonyc.chain ,January 11,2017;

2.4.2.4 Developmental Disorders:

Congenital developmental anomalies of cerebellum reflect in genetic and teratogen factor , the cerebellum have long embryonic development which lead to affect with toxin , chemical ,viral infection , radiation and ischemic-hypoxic insult(Fredericks, etal .2012) .

Developmental malformations of the cerebellum are diverse and can be secondary due to genetic mutations as in joubert syndrome or due to mechanical compression like in chiari 2 malformation due to small posterior fossa or pre, peri & postnatal insults (Greed ink, etal.2012)

The malformation of the cerebellum may be focal or associated with brain stem or cerebral abnormalities. congenial hypoplasia of some or absence of cerebellum may be occur because the vermin forms after hemisphere there for most likely to be absent the most common types occur are dandy walker syndrome and Arnold-chairi malformation, the first one It consists of a groups of anomalies in which there is cerebellar vermis hypoplasia and cystic dilatation of the fourth ventricle and occur ballooning of posterior half of fourth ventricle(Fredericks, etal .2012)

Which can be well appreciated on MR. Dandy-Walker malformation can be differentiated by the presence of enlarged posterior fossa, elevation of tentorium and torcula herophilli, absent vermis , The cerebellar hemispheres can be hypoplastic as well. Obstructive hydrocephalus is present in 75% of the cases due to associated aqueduct stenosis (Patel and Barkovich , 2002)

The Dandy-Walker syndrome, indicating bilateral vestibular loss ,there is partial or complete agenesis of the cerebellar vermis, cystic formation of the posterior fossa communicating with the fourth ventricle, and hydrocephalus. About 80% of the diagnoses of Dandy-Walker are made by the age of 1 year of age. Dandy Walker is often accompanied by other malformations, the most common of which is agenesis of the corpus callosum. (Thimonync, etal.2017)

The second type of malformation occur when the cerebellum herniation to brain stem and called Arnold-Chiari malformation and had four types as degree of herniation(Michael and Bernard ,2005)

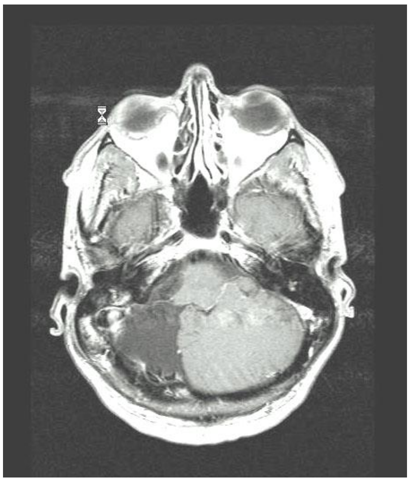


Figure No (2-16): Shows Patient with congenital absence of one cerebellar hemisphere(MRI image)

. http//dizzy- doctor.com/thimonyc. chain ,2017

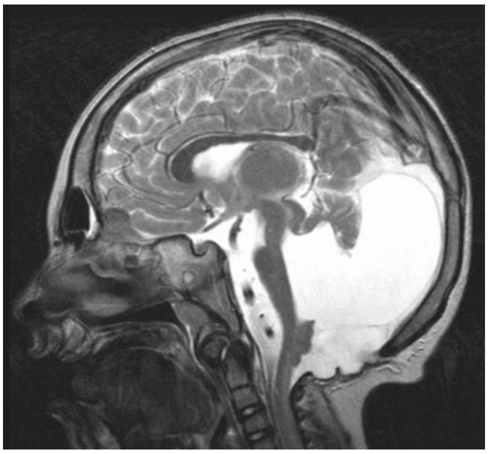


Figure No(2-17): Describe DWS with dysplasia of the pons and cerebellum in an 8-year old. T2 weighted sagittal MR

https://upload.wikimedia.org/wikipedia/commons/9/9d/Dandy-Walker-Variante_MRT_T2_sagittal.jpg

Figure No(2-18): Shows Patient with an Arnold Chiari Malformation
http//dizzy- doctor.com/thim onyc.chain ,2017

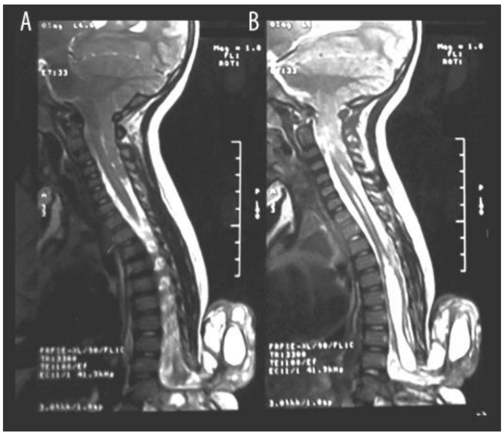


Figure No (2-19): Describe The Chairi malformation type2 in sagittal T2weighted image with evidence of caudal displacement of cerebellar vermis and medullaoblangata with spinopifidahttps://www.ncbi.nlm.nih.gov/pmc/articles/PMC4364256/ .

2.4.2 .5 Infection disorders:

A Variety of organism can affect the cerebellum and the central nervous system , either bacteria or virus or parasite . Encephalitis occur due to viral and associated with polio, mumps ,rubella, chicken pox and herpes viruses.

The most common one is acute cerebellar syndrome, which due to viral and lead to acute cerebellar ataxia in young children and may be associated with meningitis , the syndrome which occur from fungal is rare (Fredericks, etal.2012)

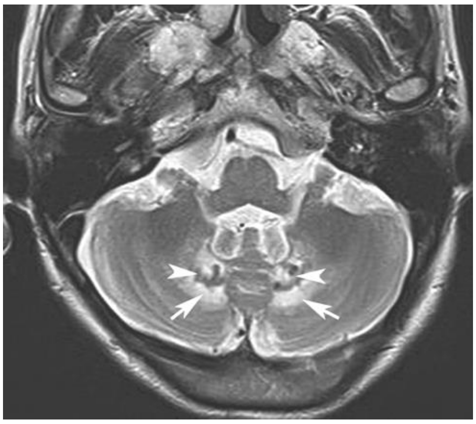


Figure No (2- 20): DescribeThe Cerebrotendinous xanthomatosis. Axial T2 image shows signal change affecting the deep cerebellar white matter (*arrow*s). Notice the abnormal hypointensity in the gray matter of the cerebellar nuclei (*arrowheads*). http://www.ajnr.org/content/34/5/925

2.4.2 .6 Vascular disorder:

Ischemic or hemorrhage of cerebellar is very seldom , the cerebellar hemorrhage estimate about 10% from total crinal hemorrhage but the stroke have few present , when hemorrhage occur is totally absence of walk or stand and coma occur after few hours ,the cerebral hemorrhage manifested to headache, vomiting , vertigo ,dizziness and unsteadiness of gait(Fredericks, eta l .2012)

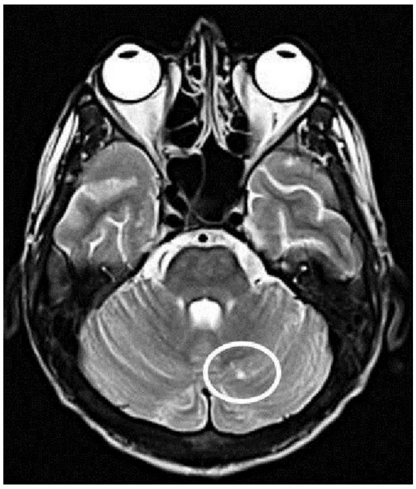


Figure No(2- 21):Describe Acute left cerebellar stroke which appear as hyper-dense lesion on T2 weighted MRI of the brain(encircledhttps://www.researchgate.net/figure/Acute-left-cerebellar-stroke-hyper-dense-lesion-on-T2-weighted-MRI-of-the-brain_fig1_280787949

2.4.2 .7 Intoxications Disorders:

The cerebellar pathology may include toxin, a chemical drugs, solvent and heavy metal which affected in cerebellum directly or encephalopathy

The drugs given in high doses cause cerebellum dysfunction.

Recreational or accidental exposure to wide volatile of solvent cause ataxia also poisoning with heavy metal cause promint nervous syndrome such as ataxia and there are mercury, magnesium, bismuth and thallium (Fredericks, etal .2012)

Ethanol and many anticonvulsant medications such as phenytoin and carbamazepine are cerebellar toxins. Ethanol characteristically causes atrophy of the cerebellar vermis. This is true even for exposure in utero (AuttiRamo, et al. 2002).

Certain types of cancer chemotherapy, such as cytosine arabinoside (Zesiewicz,et al. 2012), are cerebellar toxins. Lithium, given for manic-depressive disorder, is a cerebellar toxin. (Thimonyn, etal .2017)

2.4.2 .8 Physical or mechanical trauma:

Direct or mechanical trauma to head may cause hemorrhage to cerebellum make cerebellum dysfunction, the cerebellum also is high oxygen consumption in the nervous system therefore it sensitive to oxygen deprivation due to cerebral hypoxia, also sensitive to thermal injury which occur due to hemorrhage or prolonged fever, also accidental or therapeutic of ionization radiation may cause injury (Fredericks, etal .2012)

2.4.2 .9 Metabolic Disorders:

A number of inherit or acquired metabolic disorder associated with cerebellum dysfunction. disorder of lipid ,pyruvate salute ,urea cycle ,lactate metabolism and some aminoaciduria's associated with cerebellum symptoms almost occur in childhood and occur cerebellum dysfunction due to acclamation due to neurotoxic substance such as ammonia which lead to ataxia (Fredericks, etal .2012)

2.4.2 .10 Demyelinating or dyesemyelinating Disorders:

Many of nerves fiber are myelinated for normal impulse propagation , myelin is distributed in many disorder either inherited disease or acquired and that affect in impulse speed and quality of conduction, the myelin may be destroyed or damage in this disease and the most common one is multiple sclerosis in central nervous system and have may feature such as visual and accumulator disturbance , urinary dysfunction and cerebellar deficit which progress to cerebellar dys function (Fredericks, etal .2012).

Various demyelinating diseases like multiple sclerosis, acute disseminated encephalomyelitis and progressive multifocal encephalopathy. Enhancement is variable and lesions may be non-enhancing or may show open ring type of enhancement along the leading edge of inflammation. (Arora, etal .2015).

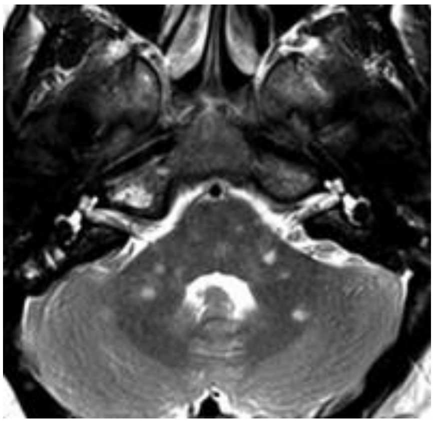


Figure No (2-22): Shows The multiple scoliosis in axial T2 MR Image represent as hypo dense dots in cerebellum
https://www.google.com/search?q=multiple+sclerosis+of+cerebellum+MRI+image&client=firefox-

2.5 Patho physiology of cerebellum:

Human and animal experiments performed recently have resulted in a more detailed understanding of limb movement and body posture disorders associated with cerebellar dysfunction. The delay in movement initiation can be explained by a delay in onset of phasic motor cortex neural discharge owing to decreased input from the cerebellar hemispheres. Disorders of movement termination (dysmetria), which can occur for movements at proximal and distal joints, result from disturbances of the timing and intensity of antagonist electromyographic (EMG) activity necessary to break the movement. Disorders in velocity and acceleration of limb movements result from muscular activity that is smaller in amplitude and more prolonged. The cerebellum is important for control of constant force but not for generation of maximal force. Dysdiadochokinesia is explained by a combination of the above mentioned mechanisms. During complex movements in three-dimensional space, the cerebellum contributes to timing between single components of a movement, scales the size of muscular action, and coordinates the sequence of agonists and antagonists. The basic structure of motor programs is not generated in the cerebellum. Hypotonia can be observed only in acute cerebellar lesions. Cerebellar tremor appears to result from a central mechanism, but is modulated or provoked through increased long-loop EMG responses. The common assumption that cerebellar ataxia of stance does not improve with visual feedback is true only of vestibulocerebellar lesions, not for ataxia resulting from atrophy of the anterior lobe of the cerebellum. (Diachgance, 1992).

2.6 Radiological investigation of cerebellum:

The radiological investigation of the cerebellum divided into major division first one called radiological surface area or linear measurement and the second one called the radiological volume measurements.

2.6.1 Introduction to radiological imaging:

Neuroimaging, including magnetic resonance imaging and single-photon emission computed tomography (SPECT)/positron emission tomography (PET), U/Sand CT provides several and potential valuable biomarkers for diagnosis, prognosis, and follow-up of the course of cerebellar diseases. Conventional MRI sequences (T1, T2, T2*, FLAIR, STIR, diffusion, magnetic susceptibility, angiography supply macroscopic clues for anatomical localization and diagnosis of a wide range of cerebellar alteration for example: malformations, tumor, stroke, infection, and inflammation However, these MRI sequences can fail to detect subtle histological or biochemical alteration, to differentiate properly subtypes of a given disease, and to establish robust anatomoclinical correlations. Such as neurodegenerative and neurodevelopmental diseases (Mascalchi and Vella 2012; Cuerris, etal .2013)

Unconventional MRI techniques or utilization of specific SPECT or PET radiotracers may widen the scope of neuroimaging diseases and partly overcome some of the above limitations by provide this application:

- qualitative and quantitative characterization by applying the volume-based morphometric (VBM), apparent diffusion coefficient (ADC) in diffusion-weighted imaging (DWI)for measurement of cerebellar microstructural tissue organization, tractography performed on diffusion tensor imaging (DTI), which show compute anatomical bundles composing the white matter.
- The mono- and multi-voxel proton spectroscopy can identify biochemical alterations of the white and gray matter measuring different molecules such as N-acetyl-aspartate (neuronal biomarker), choline (membrane biomarker) myo-inositol (gliosis biomarker) or lactate (anaerobic metabolism biomarker).
- In nuclear medicine can be utilized from several radiotracers to detect or track specific regional dysfunctions, such as nigrostriatal pathway, or clarify physiopathological mechanisms.
- Functional MR imaging during task execution or in a resting state may estimate disease-related functional alterations and reorganization (neuroplasticity) of the whole cerebellar syst.
- Provide pre- and postnatal imaging to detect early fetal developmental anomalies. By ultrasound and MRI.

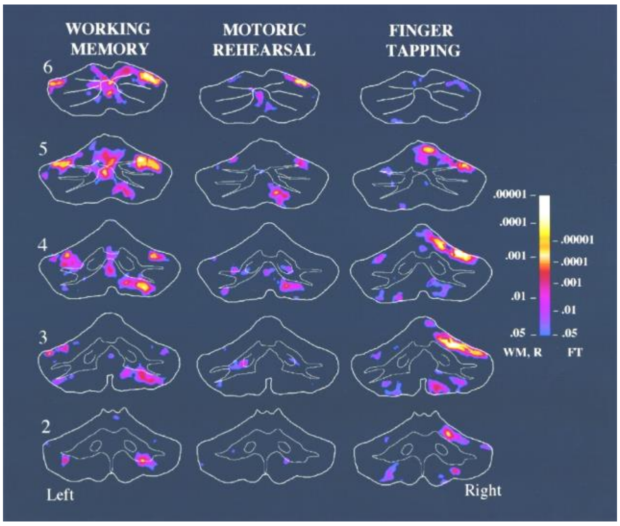


Figure No (2- 23): Describe fMRI image and utilization of image, fMRI activation in slices 2–6 for the working-memory, motoric rehearsal, and finger-tapping tasks

http://www.jneurosci.org/content/17/24/9675

2.6.2 CT procedure of measuring the cerebellum:

There are many method to calculated the cerebellum by CT either to calculate linear measurement or the volume one, but in both the patient preparation, and position were similar and using the following parameter 120 KVP=130MAS, FOV=24-25cm, slice thickness=0.5-5mm. (Ertekin, etal.2017).

In the exam of CT brain for cerebellum the CT gantry should be angulated due to occurring the beam harding artifact in CT dual,16 slice ,64slice but the spiral was reduced . Most of the CT examination done for cerebellum to exam cerebellar blood volume (CBV) or perfusion, CT of the brain can be done with or without contrast, but it is often not needed in the current ,this was similar to (Jernigan, etal.1990).

2.6.2.1 Patient preparation for CT cerebellum examination:

The patient should remove any accessories outside the examination room and wear the gown of the department ,but if need to inject contrast media to investigate the blood vessel or adoptation for neoplastic or para neoplastic disorder we apply second procedure by fasting ,and check the creatinine level to be with normal range .

The women should be asked about LMP to avoid chance of pregnant except in case to measure cerebellum in fetus done exam n second trimester as mentioned by (Weair, etal.2014).

2.6.3.2 CT technique for exam the cerebellum:

In this examination the patients lie supine in examine couch, both hand be beside the body and adjust the head to bring the outer canitho-orbial line to be perpendicular to the examine table by depress the chain down ward then put the immobilization tools to fix the patient. , in CT exam the central band of x-ray be centered on the nasion through the orbit metal line, the exam from base of skull till vertex as mentioned by (Keat and Sistroum ,2001).

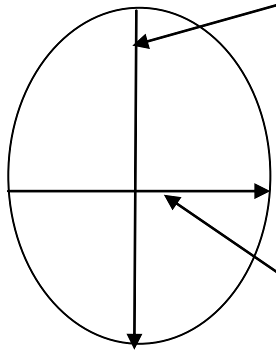
The CT gantry must be angled to avoid the beam Harding artifact because the cerebellum fond in posterior fossa and there dense bone (Nishman, etal .2017)

Head enter as first in gantry using 120 KVP,40 MAS , 5 mm slice thickness with HU 400-500 ,use contrast if need to exam the cerebellar blood supply, use matrix 512×128 ,also use gantry angulation to avoid the artifact this was acknowledged by (Weair,etal .2014)

2.6.2.3 CT cerebellum linear measurements:

The measurement done in axial mid ventricular slice appear with frontal horn (H), and always done by using software program me in CT or MRI consol. The first measure is called greater antro posterior line and this line extend from upper most border from inner table the bottom point in opposite direction(AP(Keat and Sistroum ,2019).

The second linear line called (TRV).which known as transverse diameter which start from the more widest point in internal table of skull till in RT side to the anther point in LT side opposite direction as the following illustration diagram show(Keat and Sistroum ,2019).



The cranium

Figure No (2- 24): Illustration Diagram describe the linear measurements (Keat and Sistroum ,2019)

.And this method of measuring the cranium linearly , was the same achievement which was done in the previous study done by C.C Henery etal 1989 .

2.6.2.4 CT cerebellum volume measurements:

There are many methods to calculate the volume of cerebellum by CT either manually or automatic by stereological method.

2.6.2.4.1 Manually method:

In this method pt. position was as same position of linear measurements technique then cerebellum technique with 5mm slice through the PF and 10 slice through SC all scan was done (Goel,etal. 2010). After calculate the linear measurements , which was performed inside the CT console computer or in personal computer after data collect by storage device from PACS system , with window of 2000 HU and a level of 5oo HU ,first done the measurements AP&TRV ,then the area been summed and correct with slice interval section to yield the volume (Keat and Sistroum ,2019).

2.6.2.4.2Stereological method:

This method analyze the intake cranial CT images which was prepared using CT sagittal protocol scan by using multi slice detector and apply the following parameter 120=KVP,130=MAS,0.5-0.7 mm ,as slice thickness the posterior cranial fossa was defined as anatomical area the floor formed by occipital bone up to insertion of tentorium cerebella which form the superior border of this fossa and the bias sphenoid which form The antro lateral border of this cavity anterior to curvature of clinoid process(Guzinsk ,etal .2o16).

Then point the area by point count method is based into cavlleria principle that used for unbiased estimation this of the volume of any structure , this points use for irregular shape and size may be obtain influentially with known precession (Roberts etal .1991) according to this method CT image of section 0,7 could be used to estimate PCF volume . The films were displayed on computer and the transparent square gried test with d=0.3 between the test points superimposed randomly ,covering the entire image frame the points hitting the R.O.I section surface were counts for each section and the volume estimated by modified equation(sahin ,etal .2007) and this method use in .(Ertekin, etal.2017) study.

$$V = t \times \left[\frac{SU \times d}{SL} \right]^2 \times \sum P$$

T=the section thickness of consecutive section.

SU= scale unite of the printed of the film

D= distance between the printed of the grid s

SL= the length of the sale measured printed on the film.

ΣP=the total number of points hitting the section cut surface area of ROI

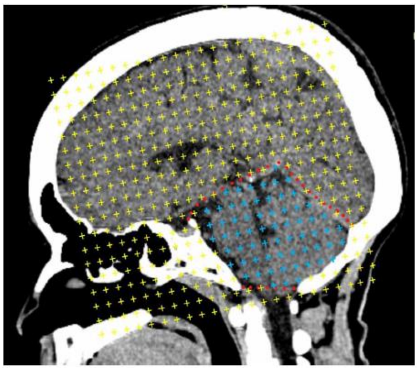


Figure No (2-25): Describe the stereological method by estimation the inter cranial cavity and posterior cranial fossa on sagittal CT image by superimposition randomly the points counting grid (Ertekin, etal.2017).

Then estimated the volume fraction which widely use in biomedical science with different parameter(Mattfeld ,etal.2003) ,to estimate the proportion of phase or component with in the whole structure the volume fraction of x phase within the y reference expressed as follow formula:

$$Vv(X\text{-}Y) = \frac{\text{volume of X-phase inY reference space}}{\text{Volume of Reference space}}$$

Where Vv(X-Y) indicate the volume fraction rate change between 0 and1 and it is often expressed as the percentage (Howard and Reed, 2005).

2.6.3.4.2 Automatic CT cerebellum volume:

For the adult pts. Use the new technique which called Flat-panel volume computed tomography (CT) systems have an innovative design that allows coverage of a large volume per rotation, fluoroscopic and dynamic imaging, and high spatial resolution that permits visualization of complex human anatomy such as fine temporal bone structures and trabecular bone architecture. In simple terms, flat-panel volume CT scanners can be thought of as conventional multidetector CT scanners in which the detector rows have been replaced by an area detector. The flat-panel detector has wide z-axis coverage that enables imaging of entire organs in one axial acquisition.

Its fluoroscopic and angiographic capabilities are useful for intraoperative and vascular applications. Furthermore, the high-volume coverage and continuous rotation of the detector may enable depiction of dynamic processes such as coronary blood flow and whole-brain perfusion. Other applications in which flat-panel volume CT may play a role include small-animal imaging, nondestructive testing in animal survival surgeries, and tissue-engineering experiments. Such versatility has led some to predict that flat-panel volume CT will gain importance in interventional and +intraoperative applications, especially in specialties such as cardiac imaging, interventional neuroradiology, orthopedics, and otolaryngology. However, the contrast resolution of flat-panel volume CT is slightly inferior to that of multidetector CT, a higher radiation dose is needed to achieve a comparable signal-to-noise ratio, and a slower scintillator results in a longer scanning time.(Gupto , etal .2009)

Figure No (2-26): Show the head CT scan

https://www.google.com/search?q=image+of+CT+machine&tbm=isch&s

figure No (2-27): Describe CT machine

https://www.google.com/search?q=image+of+ct+machine&tbm=isch&tbs=rimg:CbYy3E_1NdEKnIjgHpMfvywmHgsGwlff9_1QZ1tlrcaxoH6FtMEoqD_1a1uE-ja9XTAj4_1OdAPSDQgjTEt9LD6nT2HMJCoSCQekx-_1LCYeCEYJFwh_1MW63VKhIJwbCV9_139BnURr30scyQSssUqEgm2WtxrGgfoWxG7hwKpyW

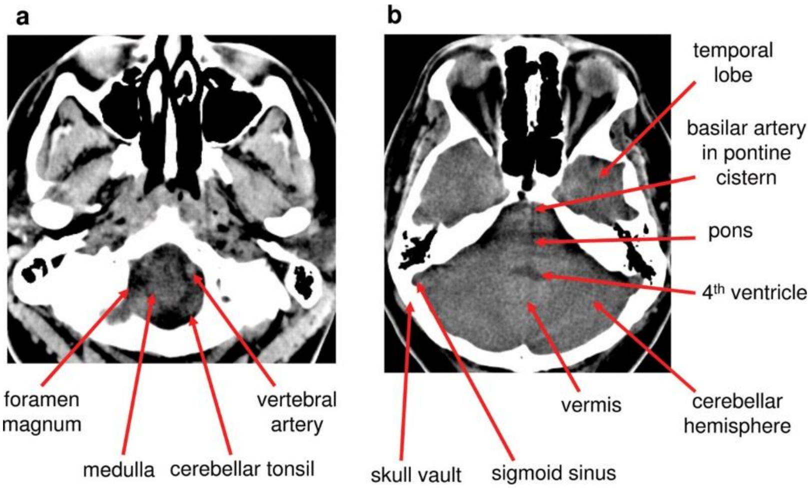


Figure No (2- 28):Show normal anatomy of the cerebellum in CT Image

https://www.google.com/search?q=manual++tracing+the+cerebellum+in+MRI+imaging&tbm=isch&source=univ&sa=X&ved=2ahUKEwjDzsaO49bgAhVIXhoKHQMXCVcQsAR6BAgHEAE&biw=1366&bih=597#imgdii=qVo-c4ucQIddMM:&imgrc=rpunJB8

2.6.3 MRI examination for cerebellum:

2.6.3.1 MRI Technique of measuring the cerebellum:

MRI procedure for cerebellum All the MRI examination provide cerebellum image with decrease the radiation hazard and more safely for women in distinguish fetus anomalies .(Leonardo Baldarcar etal 2016)

All MRI image scanned for cerebellum either by 1, 2, 4or 5 slice thickness between the image with parameter as following using spin echo sequence FOV16-18 in specimen study use fov 12 cm when selected TI weighted image apply parameter600/20/4-6,TR/TE/excitation respectively use long TR when use the cardiac gate ,TR2400-3800 msec depending on heart rate the excitation 2-4 per slice when use long TR examination.(press etal.1990). TR 2800msec with TE long 20-70msec to proton density weighted image an T2 weighted image respectively ,a 28 sec and scan sequence 200/20/1 with 24 cm fov 265*128 matrix in axial and sagittal plane was used to verify precise position of subject , which help to distinguish between the white and gray matter of cerebellum (press, etal .1990) .

2.6.3.2 Patient preparation and position for cerebellum MRI scan:

in MRI first prepare the pt. by exit and remove any metal substance then pt. ling in exam MRI table and the head adjust like the CT position then First thing apply the head coil , then apply the foams pads and ear plugs to ensure the immobilization and comfortable of patient .and we have two control line one axial and one sagittal , the first coronal and sagittal one cross the nasion area ,the second coronal one pass just at the external orbital line level then the scan start from vertex till the base of skull (Westerbrook ,2014).

2.6.3.3 MRI cerebellum measurements:

2.6.3.3.1 MRI cerebellum linear measurements:

In fetus case just measure the linear measurements when scan the cerebellum , and the scan must be after 14 weeks of pregnancy after formation the cerebellum tissue and use 7 tesla machine .

In linear measument apply the measuring value measuring TRV,AP diameter of cerebellum , but in case of fetus measuring the linear measuments to access the fetus age , as addition factor of cerebellum measurements for estimation fetus age (Goel,etal .2010),but in adult case added measuring of the height of cerebellum.

The Tran's cerebellar diameter (TCD), vermal height (VH), and vermal anterior–posterior diameter (VAP) were manually measured on the cerebellum segmentations. TCD was defined as the maximum distance from the right to left hemispheres in the coronal plane. On the midsagittal vermal slice, VH and VAP were calculated. VH was the greatest inferior to superior distance, and VAP was the distance from the apex of the fourth ventricle to the posterior extent of the vermis, and the most common used for embryo anamolyisis using MRI (Julia.A.Scott etal 2012).

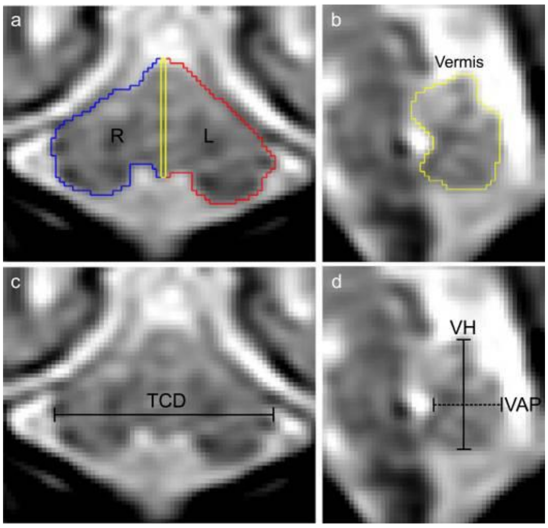


Figure No (2-29): Describe The linear measurement of cerebellum in MRI

Example of cerebellum linear dimensions and volumetric segmentation at 25 gestational weeks. **a**, **b**) The perimeter of the cerebellum was manually drawn then labeled as right hemisphere (*blue*), left hemisphere (*red*), and midsagittal vermis (*yellow*). **c** Transverse cerebellar diameter (*TCD*) was measured at the maximum distance in the coronal plane. **d** Vermis height (*VH*; *solid line*) and anterior–posterior diameter (*VAP*; *dashed line*) were measured on the midsagittal slice Cerebellum

https://www.ncbi.nlm.nih.gov/core/lw/2.0/html/tileshop_pmc/tileshop_pmc_inline

2.6.3.3.1 MRI cerebellum volume measurements

2.6.3.3.1.1 Manual MRI volume:

In the volume measuring using the neuron imaging MRI either manually or automatic measuring MRI volume measuring.

In the past the cerebellum measurement done manually by cadaveric by slices the cerebellum in many sections, then calculate the volume , first calculate the linear measurement (horizontal –vertical) and the inter slice section is 4cm, and calculate the height after section the hemisphere in slices with section interval 1cm,after that calculate the volume by multiplying the horizontal x vertical x height x interval section such as C.CHenery etal (C.CHenery etal.1989) this manual method apply after the patient death . the second procedure by measuring the volume by same procedure of measuring cerebellum volume by CT in the using the data of MRI mage to calculate the volume manually(Keat and Sistroum ,2019).

2.6.3.3.1.2 Automatic MRI volume:

After enter the neurology imaging the cerebellum volume calculate from the PACS system by applying advanced software programme in computer then analysis image to calculate the volume , which reduce the time such as CATTK, wolfrom mathematica, mat lab ,analyizedirect , Linux which calculate the volume of cerebellum automatic after certain to it the started point of appearing the cerebellum in the MR image till ending the cerebellum scan with consideration the interval sectional gaps and it is more accurate procedure which calculate the structure of interest after was delineated by manually tracing which outline in subsequent slices on an MR image, and the computer then calculates the volume of the structure (Koller etal 1981).

AS protocol imaging of MRI cerebellum, Obtain many images for MRI cerebellum coronal ,sagittal and axial then collect and process to have the measuring of cerebellum either surface or linear or volumetric measurements. And that occur after trace the area of cerebellum either manual or automatic that procedure called cerebellum stereology.

As could compare the cerebrum and cerebellum measurements by Total cerebral and cerebellar volume were quantified by using a three-part fully automated image analysis process, or hand-traced measures of cerebellar volume were highly reliable as method of Koller ,method (Koller et al 1981)the image is first label manually then transfer to image analysis program me which is advanced software using in computer of MRI consoles to calculate the volume or after saved image in storage device from the PACS system and process to analyze the volume by software progrmme

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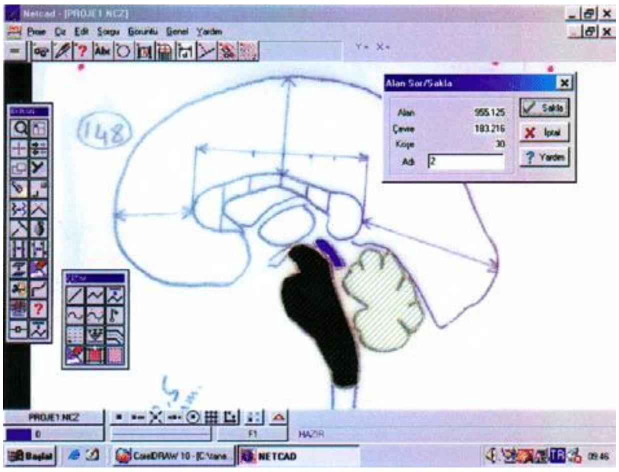

Figure No(2-30): Describe The manual tracing the cerebellum Diagram of the outline contours of the midsagittal sections of the brain stem and cerebellar vermis showing the calculations of the areas.
https://www.researchgate.net/figure/Diagram-of-the-outline-contours-of-the-midsagittal-sections-of-the-brain-stem-and_fig2_26339493

Some methods also use a semi-automated technique, where a rater will manually select anatomical landmarks, and a computer program will use this to assist in defining the structure and calculating its volume (Keller and Roberts, 2009).

Using a standardized computer program reduces the issue of inter-rater and intra-rater reliability that exist in manual rating scales. Automated methodologies can also be applied by a researcher with less specialized knowledge about neuroanatomical, and it can be used to assess large datasets relatively easily (Keller and Roberts, 2009).

Automated methods have been shown to give quantitative estimation of structures that can be easily delineated on MR images, such as grey matter, brain parenchyma, and ventricular volume (Keller and Roberts, 2009), but new methodologies have applied similar methodology on a number of deficits such as WMLs (Caligiuri et al., 2015) .

2.6.4.3.1.2 .1 How MRI calculate the cerebellum volume automatic:

Three volumes were chosen for quantitative validation; for each MRI cerebellum protocol volume was acquired using a different PD/T2-weighted echo sequence, and a different field of view size. For each volume, some axial slices were selected, such that the entire range of the image volume from low to high slices was covered means from base of skull till dis appeared the cerebellum. For each of these slices a reader or researcher traced the cerebellum contour manually, and the manual cerebellum contour was compared with the automatically drawn contour. To quantify these results, the similarity index described by Zijdenbos (Zijdenbos, etal.1994) derived from a reliability measure known as the kappa statistic. The similarity of two segmentations and is given by a real number defined because the similarity index is the ratio of twice the common area of the segmentations to the sum of the sizes of the individual areas, it is sensitive to both size and location. Therefore, two equally sized region regions that overlap each other with half of their area results in and a region

There were three steps to measure cerebellum the first step uses histogram analysis to localize the acquired from several different scanners. The algorithm consists of three incremental head, providing a region which must completely surround the brain the second step uses nonlinear anisotropic diffusion and automatic thresholding to create a mask that isolates the cerebellum within the detected head region. Using this mask as a seed, the final step employs an active contour model algorithm to detect the intracranial boundary. This algorithm has proven in the presence of RF inhomogeneity and partial volume effects. The MRI cerebellum segmentation algorithm is in regular use for studies of Multiple Sclerosis lesions, for studies of MRI- PET registration, and for studies involving image compression, where the non-brain region such as measuring the lung volume such as cystic fibrosis(altikines .m.stella.etal1998)

2.6.3.4 MRI image analysis for measuring the volume:

2.6.3.4 .1 MRI image segmentation:

In neuroimaging procedure before calculating the volume must segmentation the image and exclusion the brain to study the cerebellum and this segmentation either manual or automatic ,manual
Segmentation or delineation by an expert requires huge effort
since consuming time and be so difficult when reading huge subjects A few semi-automatic methods have been developed offering large structure parcellation (Weier et al., 2012) Fully automatic methods appeared in the last three years. Was published a method
Using for random boundary classification. Which offers comprehensive visualization options in 2D and 3D, but also provides comprehensive tools for analyzing structures inside the human body. Determine the minimum and maximum extent of a particular object, e.g. a tumor perhaps the size of surfaces and cross-sections of certain elements, such as the vessels, also able to measure the porosity of objects, like the bones. Recently Yang et al. (Yang et al. 2o13) which preserve the time and effort more accuracy.

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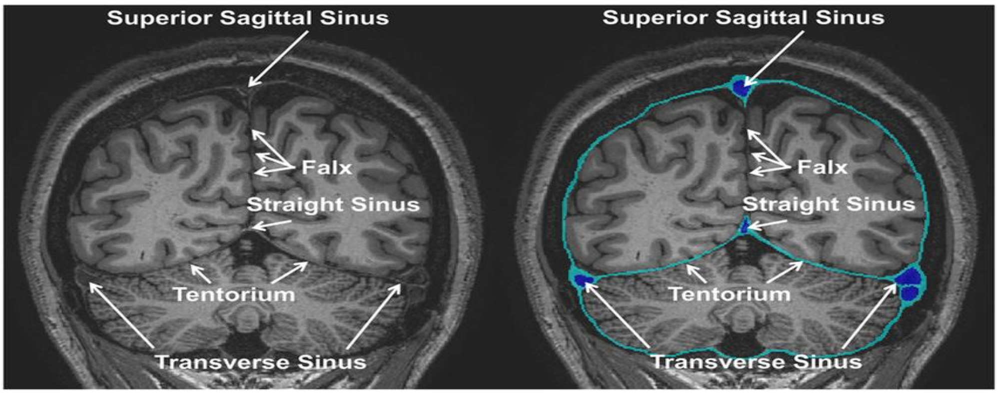


Figure No (2- 31):Describe Manual cerebellum segmentation https://www.researchgate.net/figure/Segmentation-of-the-dura-mater-Coronal-T1-weighted-MRI-left-and-outlines-of-the-dura_fig9_307724002

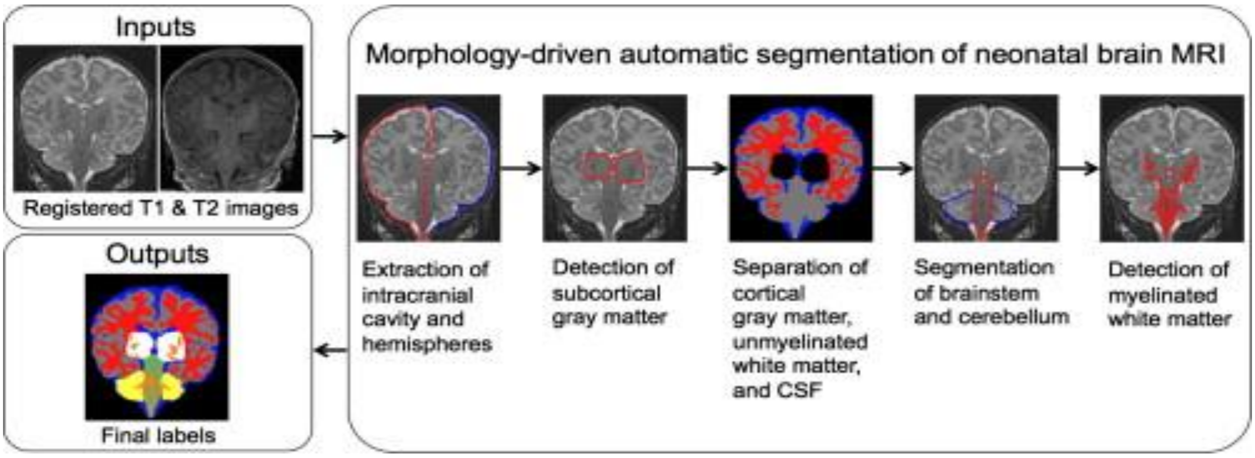


Figure No (2- 32): Describe automatic segmentation of cerebellum https://www.google.com/search?biw=1525&bih=734&tbm=isch&sa=1&ei=yAR9XJ-hNYOQkwWd5aOgAQ&q=image+of+automatic+cerebellum++segmention&oq=image+of+automatic+cerebellum++segmention&gs_l=img.12...7458.33981..37278...1.0..1.494.8588.0j25j16j1j1......0....1..gws-wiz-img....

Figure No (2-33):Shows MRImachine3tesla

https://www.google.com/search?q=MRI+Machine

Figure No (2- 34): Shows MR Machine with head coil

https://www.google.com/search?q=MRI++for+head+scanning+image&client

2.6.4 Linear cerebellum measurements by U/S:

This examination is done mainly during the pregnancy in second trimester and during the cerebellum developmental in 14-22 weeks which start to visualize the cerebellum clearly and can be distinguish , the TCD is one of new unique parameter which adding in sonographeic measurement to be using during pregnancy which more accurate to assess the gestitation age (GA). Than the other sonogrphical parameter. (Goel, etal .2010).

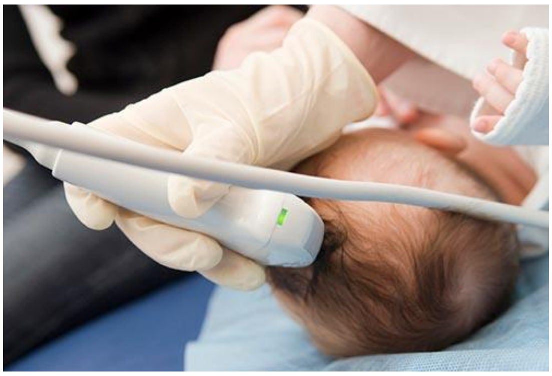


Figure No(2-35):Shows U/S of head scanning for baby https://www.google.com/search?q=Ultra+sound++For+head+scanning+iimage

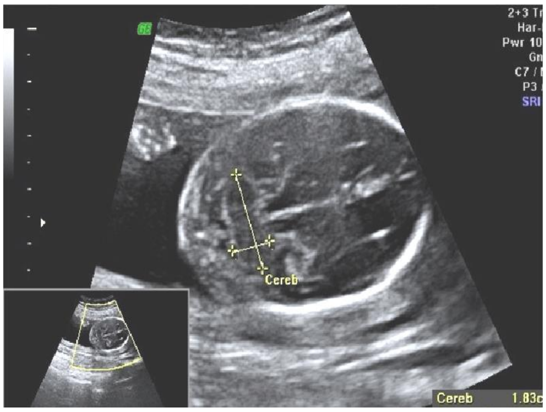


Figure No (2- 36): Shows ultrasound image with linear measurement https://www.researchgate.net/figure/17-GW-fetus-ultrasound-image-transverse-section-of-the-head-of-the-fetus_fig1_32329816

2.6.5 Cerebellum investigation by SPECT:

The cerebellum investigated by nuclear medicine commonly when there was problem or pathology in cerebellum such as movement disorder or there was dementia and the diseases appear either hyper perfusion or hypo perfusion ,in case Alzheimer disease appear as bilateral perfusion defect in temporal and partial region in brain, but hypo perfusion in cerebellum which is opposite appearance in case of movement disorder appear as hyper perfusion(Glowniak,etal .2011).

2.6.5.1 The Technique:

The patient lie supine in the gamma camera coach after preparing first give him /her instruction and procedures of exam and the time of it then remove any metal and address the gown and been fasting 4hours at least the head adjusted with the orbital metal line be90degree on the table.pt been stable by immobilization pads, take axial and coronal image the radiophrmatical used is: Tc-99m HMPAO (sathekage , etal .2002)

2.6.5.2 The Scanning:

SPECT was performed after intravenous injection of 740 MBq of Tc-99m HMPAO, The radiopharmaceutical was prepared according to the manufacturer’s prescription with fresh elute, and injected within 20 minutes after its preparation. Patients were injected in a quiet and dimly lit room. Imaging started 20-30min after injection. Tomographic images were obtained using a single-headed rotating gamma camera (SOPHY DSX) equipped with low-energy, high-resolution collimator and connected to a NXT computer. Data were collected from 64 projections in the 140 kev photo peak (20% window) over 360o in 64x64 matrices, with acquisition time of 30 seconds per view. A zoom factor of 1.6 was used. Orthogonal, transverse, coronal and sagittal planes were generated by filtered back-projection using a Weiner filter, followed by orbit meatal reorientation of the reconstructed volume. The images were assessed qualitively by visual interpretation. Regional cerebellar blood flow (rCBF) was performed by defining two regions of interest (ROI) around each cerebellar hemisphere9. Cortical ROI were drawn using a semi-automated technique at canthomeatal (CM) +5.5cm9. Cerebellar-to-cortical ratios were obtained using count data from a cerebellar section at 1.75cm above CM line, compared with count data from a cortical section at 5.5cm above CM line (sathekage, etal .2002).

There are many case which contraindicated to perform nuclear medicine exam to cerebellum such as allergic to drugs, or when there was renal or hepatic disease or there was cardiovascular instability (Glowniak,etal .2011).

2.6.5.3 The Data acquisition:

All data reconstruction and acquisition with computer of Gamma camera which provide with software programmer to calculate the volume and any other require such oxygen consumption, glucose metabolism, blood flow to cerebellum comparing to cerebrum and volume (sathekage, etal .2002)

Figure No (2-37): Show the gamma camera machine https://en.wikipedia.org/wiki/Single-photon_emission_computed_tomography#/

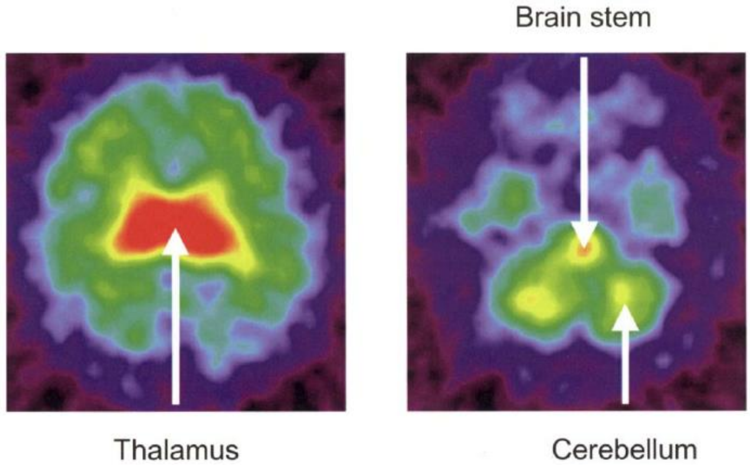


Figure No (2-38): ShowsThe SPECT image of cerebellum https://www.researchgate.net/figure/SPECT-images-acquired-4-hr-after-Administration

2.7 Previous studies:

In the prospective and analytical study of the Murshed et al 2003 which about the morphtic assessment of the brain stem and cerebellar vermis and affecting of age and gender by using MRI ,they assess cerebellum volume and the relation of the volume with age , which consider as comparative path physiological study .

They study 70 females ,50males,there age range were in (13-70) years old, the purpose to assess the relation of the significant sex ,age difference in vermis area .they were divided the study group in three groups and found that ,there were no significant relation of sex and age in vermin area but notice that it was atrophied especial in men over 70 years old and that justify due to loss of purkinje cell in vermin area.

Also study show that there are decline in vermin area in females when age increase more than men, there are significant morphological change of the cerebellum relating to sex and age.

In the lohrd .et al 2003 study the effect of age on the volume of cerebellum and volume of sub cortical structure such as (grey & white) matter volume they calculated the volume automatically after division the anatomic structure to 16 sub divisions ,their result were showed that the cerebellum volume have liner relationship which means negative propagation when the age increase the volume decrease ,their study consider as the base of abnormal age change in neurological study.

The unique research of the Haogenam et al 2012, they were determination of cerebellum volume in generally in elder population, they were found that the cerebellum volume and cerebellum sub cortical structure were been decreased when the age was increased ,and that attributed to present of low or fewer neuron in cerebellum ,and same occur in sub cortical structure volume ,the average of decrease of cerebellum volume was 0.35 ml per year in increasing age , and they justified by decline of the white matter ,also they notice that when found the WML directly associated by small cerebellum volume, also they found that the cerebellum volume decrease in women than men due to reduction of white matter in women more than men by 0 .09 ml per /year ,the white was declined rather than the gray matter , the cerebellum volume was less than cerebrum due to increase the white matter in brain more than cerebellum .

In the research of automatic MRI cerebellar size measurement using active appearance which authored by M price et al 2014 was obtained. Their study were found that the cerebellum has been as important structure which help in diagnosis of some disorder such as alcoholism ,autism they use the (CATK)which could to delinate the cerebellum hemisphere and division the vermial into three veirmal groups

The volume which was calculated automatically was smaller than the volume which was calculated manual ,they were divided the sample in to groups by auto and manual methods for cerebellum volume and verimal areas ,their study were showed that the auto measurement was smaller than the manual one.

In the Michael et al 2002 in their prospective and analytical study which was published about the cerebellum volume and cognitive aging they found that the frontal lobe and temporal were atrophied and the cognitive was declined due to increasing in age .

The research also was studied the cerebellum volume and the relation of cerebellum and sub division with the age , they were found that the cerebellum volume and all surface and vermin structure was decreased when the age was increased and that attributed to degeneration of neurological structure .

In the Oguro. H et al 1998 study which was descriptive and analytical study by ,2 T MRI they were studied 152 volunteers(81men – 71 women) ,they were studied that their was changing in morphtic structure in the cerebellum volume, and they was found that there were stronger significant association of cerebellum volume and vermin area of cerebellum with age when the age was increased were reduced in volume especial in men after 70 years.

Both men and women supra brain atrophy which progressed by decade

In the analytical and stereological study of the C.C Henery et al 1989 which with title of cerebrum and cerebellum with fixed human brain efficient and un biased was estimated of volume and cortical surface area . They measure three surface area to each cerebrum and cerebellum hemisphere (horizontal - vertical)and the third one called height which measure in lateral section and there are 4cm between section and section ,each cerebellum hemisphere is in sected into vertical and horizontal line with 1cm interval.

In their study the measurement error was decreased due to superimposition of lattice section more than once .their study was showed the cortical was greater in male rather than female , cerebral coupled with sexual dimorphism in cortical volume .

Also there are greater size of brain in the male rather than females and that attributed to great (length- width)+ volume, were appeared in male hemisphere which be more heavier than female and that lead to volume of cerebellum was larger in male rather to female .

In the stereological study which was achieved by P .R. Escalon et al 1991to assessment of the human cerebellum volume by sing MRI machine, on 37 volunteer with sage range 24-79 years old. They found that the female subject had smaller cerebellum volume comparing with male in the same age ,and no significant evidence of cerebellum volume with age and their attributed to loss of cerebellum neuron with age which was declined with volume

This study demonstrate the feasibility of using MRI image along with stereological method to assess the human volume of cerebellum, thereby providing research tool to correlate cerebellar morphology with function

Table 2-4Show the cerebellum volume of present study and other population:

Auther/ year	Population	Age range Years old	Sample size	Volume for male	Volume for female	note
Ekinietal/2008	Turkian	16-76years old	24 total 12 males 12females	117,75cm3±10.7cm^3	111.83cm3±8, 0cm3	
TejalNetal 2003	American	14-68years old	100 total 44 men 54 women	6.16×10^{-3} cm^{-1}	5.78×10^{-3} cm^{-1}	
JiaFeng etal May 2011	France	4-18 years old	325male 173 female	133.82cm3	127.35cm3	
YOOYong Hoogndam etal 2012	Koren	12-68years old	44 total	129,7±0.25ml3	126.2±1.22ml3	
Mah etal 2013	Canada	>28days< 18 years	23child			104cm3 Volume mean for all

Chapter Three

Material and Methods

Chapter three

Materials and Methods

3.1 Materials:

3.1.1 Study population:

This study was performed on 200 participants came to MRI center with different complains , all of them underwent MRI brain examination for different clinical reasons, all images were diagnosed by radiologist were normal scan results .

All were divided into two groups , group one were 100 participants 61were females 39 were males, group two were another100 participants were 59 were females and 41 were males , all the participants age were (14-80) years old.

In first group cerebrum and cerebellum linear measurements was taken, the second group cerebellum volume and vermeil area measurements was applied.

3.1.2 Area and duration of the study:

This study was performed in Khartoum state Sudan in MRI Radiology department in Yestbshron Medical Center branch of Omdurman, during the period2014-2018.

3.1.1.1 Inclusion criteria: All participants have under went to MRI brain scan and their image diagnosed normal MRI brain

3.1. 1.2 exclusion criteria:

Any participants have problem to perform MRI brain such as participant have metallic foreign body or brain clips or any patient has previous history of infraction or any cerebellum disorder such disease of movement or balance .

3.1.3 Equipment:

The machine was open machine, manufactured in America in 2005 and assembly in China, General electrical (GE) exit 0.2 Tesla

The RF Range in examination from (512-192) HZ.

The slice thickness used in MRI brain was 5mm routinely except in exam small region such as pituitary gland or optic foremen.

The matrix (option) 256x256 or 512x512

Field of view (option) small, medium and large, used head coil for brain exam, head support pads and picture archiving and communication system (PACS).

3.2 Method:

3.2.1 Examination technique used in measuring cerebellum:

Three axial (T1,T2, T1with flair), one sagittal T1and one coronalT2 section as routine .The measurements were done in slice as follow axial T2 FSE, sagittal TI SE and coronal T2 FSE.

All were prepared for MRI examination by removing any metallic substances ,anesthesia was applied were some case that need to be anathesied ,the contrast media was applied when case need to be applied.

Head coil was applied, foam pads and ear plugs were applied to ensure the immobilization and comfortable of participants.

Two control lines were used , one axial and sagittal were obtained , the coronal and sagittal planes cross the nasion area ,the coronal plane pass just at the external orbital line level then the scan was started from vertex to the base of skull .

3.2.2 Measurement:

All MRI images were taken from the PACS system , and the volume and linear measurement were obtained.

In this research the cerebellum is measuring by two ways:

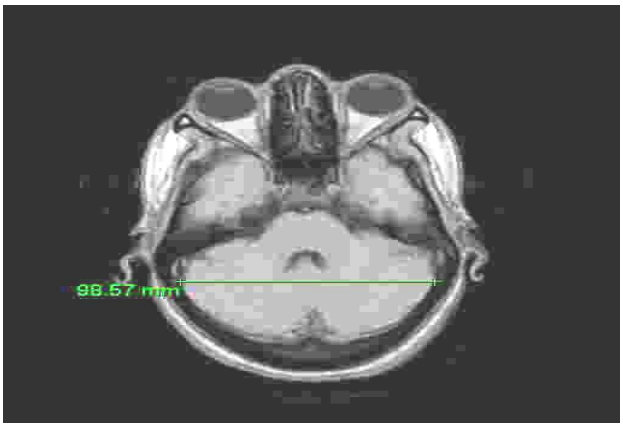
1\linear measurement 2\volume measurements

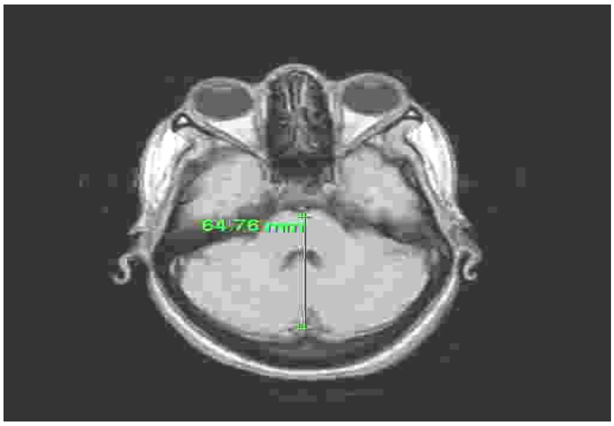
3.2.2.1 Method of linear measurement:

3.2.2.1.1 The axial:

3.2.2.1. 1 .1. Axial cerebellum general (maximum):

First measurement was taken in axial T2 FSE in region of interest for the cerebellum at the inner borders. Then the creaser was positioned at the wider point in inner border of left side of cerebellum and it was traced to another symmetrical right border of cerebellum, and the reading was taken ,and this measurement was called maximum cerebellum width at axial image .Then from the midline and from upper point the creaser was positioned ,then it was traced into lower bottom end in another symmetrical side which was passed at mid line of cerebellum ,and the reading was taken ,which was called maximum cerebellum length at axial image.



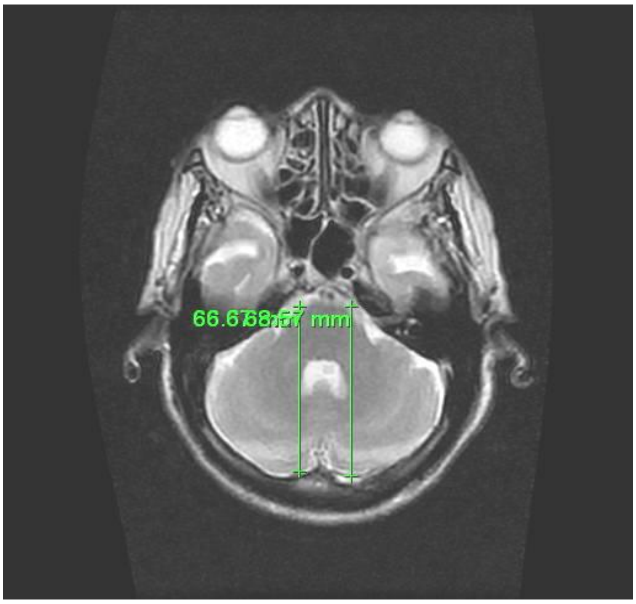


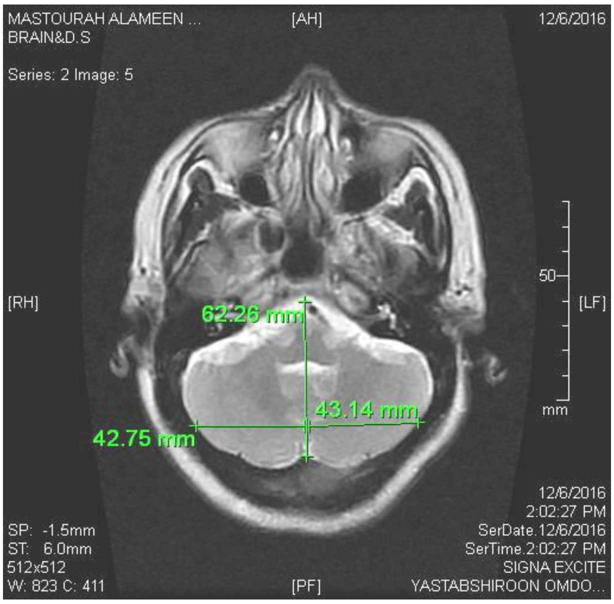
A B

Figure No(3- 1): Shows Axial image example of measurement the axial cerebellum Maximum width in image A , but in B one Showed the method of maximum of cerebellum length

3.2.2.1.1.2 Axial measurement of the cerebellum for each hemispheres:

First measured was taken in axial T2 FSE in region of interest in the cerebellum in the inner border of cerebellum the creaser was positioned at the mid of the RT hemisphere then it was traced till was reached the lower bottom end and the reading was taken which was called RT hemisphere length of cerebellum at axial image then the creaser was transferred to the second side in LT hemisphere and the creaser was positioned in middle inner border and was drawn till it reach the lower bottom end and the measurement of the length of LT cerebellum hemisphere was taken which was called LT cerebellum length hemisphere at axial image , then the creaser was transferred to inner border of RT hemisphere at the middle of left surface at more wider area and it was drawn till it reach the mid line of cerebellum and this reading was called RT hemisphere width of cerebellum at axial image ,after that the creaser was turned at the more point wider in inner border of RT surface of left side of cerebellum then it was drawn till mid line and the measurement was taken which was called LT hemisphere width of cerebellum at axial image.





A B

Figure No (3-2): Shows The axial T2weighted image F SC, A: represent the cerebellum length of each hemispheres and the B Image represent the cerebellum width for each cerebellum hemispheres

3.2.2.1 .1.2 Maximum cerebrum measurement at axial plane:

3.2.2.1. 1 .2.1 Maximum cerebrum measurements in axial plane :

The image was selected where the lateral ventricle appears as capital (H) in this point the measurement of cerebellum was taken , the creaser was traced from inner border of the midline till the bottom and that was called general or maximum cerebrum length at axial ,then the creaser was traced at the wider part in right side of the cerebrum then it was drawn to left symmetrical side and that was called general or maximum cerebrum width at axial image.

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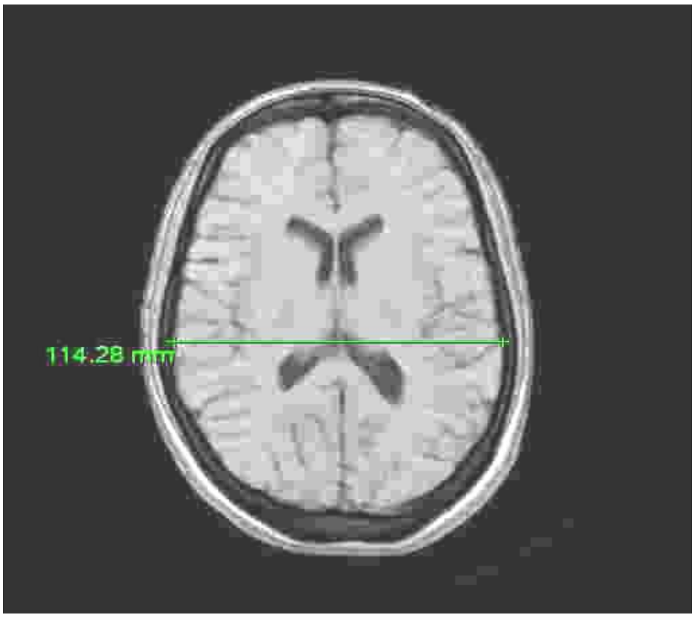

Figure No (3-3): Shows The example of measuring maxium general axial width of cerebellum in T1weighted image

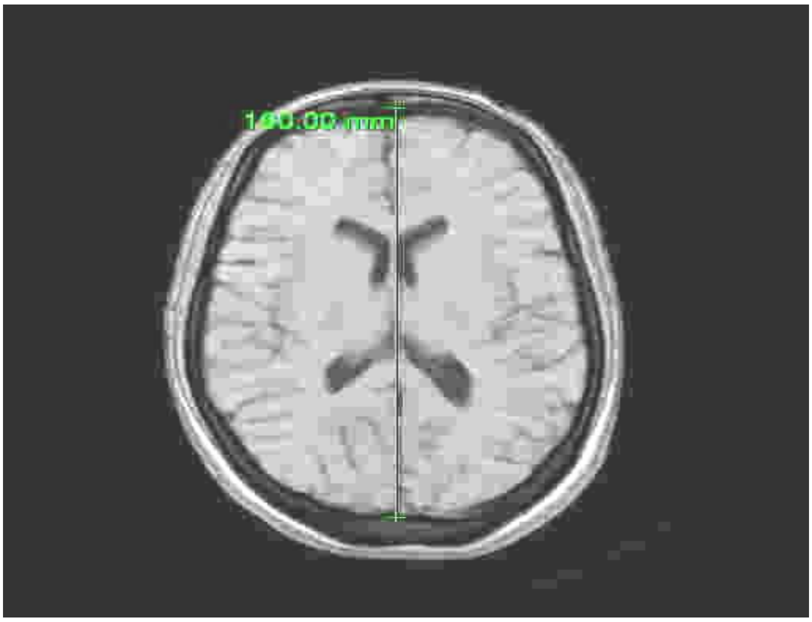

Figure No (3-4): ShowsThe example of measuring maxium axial length of cerebellum in T1weighted image

3.2.2.1.1.2.1 Axial measurements of the Cerebrum for each hemisphere:

Then image was selected till the area of lateral ventricle was appeared as capital letter (H)in this point the measurement of cerebrum was taken ,first thing the creaser was positioned at inner border of RT hemisphere of brain then it was traced till it was reached the lower bottom end , and in this point the reading was taken which was called RT hemisphere length of cerebrum at axial image , then the creaser was transferred to the second side in the LT hemisphere and the creaser was positioned at middle inner border of LT hemisphere , and it was traced till it was reached the lower bottom end of LT hemisphere and the measurement of the length of the LT cerebrum hemisphere was taken, which was called the LT cerebrum hemisphere length at axial image , then the creaser was transferred in to inner border of the RT hemisphere at the middle of right surface at more wider area and it was drawn till it was reached the mid line of cerebrum and this reading was called RT hemisphere width of cerebrum at axial image ,after that the creaser was turned at the more point wider in inner border of the LT surface of left side of cerebrum then it was drawn till mid line and the measurement was taken which was called LT hemisphere width of cerebellum at axial image.

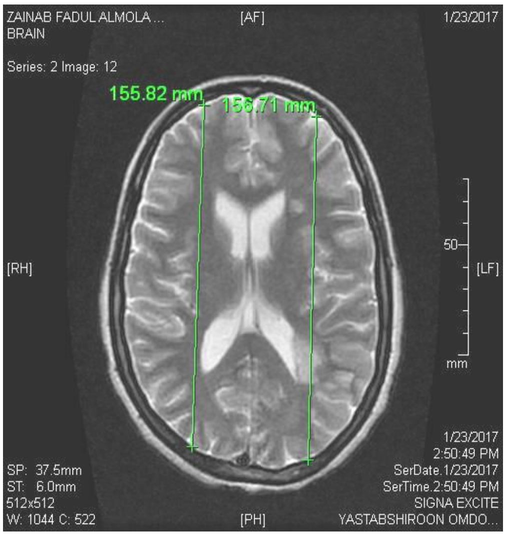

Figure No (3-5): Shows T2 weighted image of the linear measuments of cerebrum length for each heimspheres

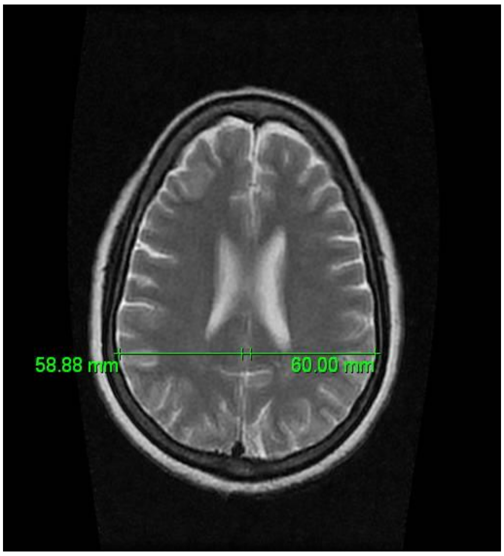

Figure No (3-6): Shows T2 weighted image of the linear measuments of cerebrum width for each heimspheres

3.2.2.1.2 Sagittal Cerebellum:

The image was selected where the brain stem which including the medllua oblangata and pons were appeared and at that point the cerebellum length and width reach the maximum ,then the creaser was positioned at most upper point and it was drawn till reach the lower point in another side and this measuring was called cerebellum height at sagittal or called crino caudally reading of cerebellum at sagittal image.

Then the creaser was positioned in more wider area at RT side then creaser was drawn till the symmetrical opposite side which was called the width of cerebellum at sagittal .

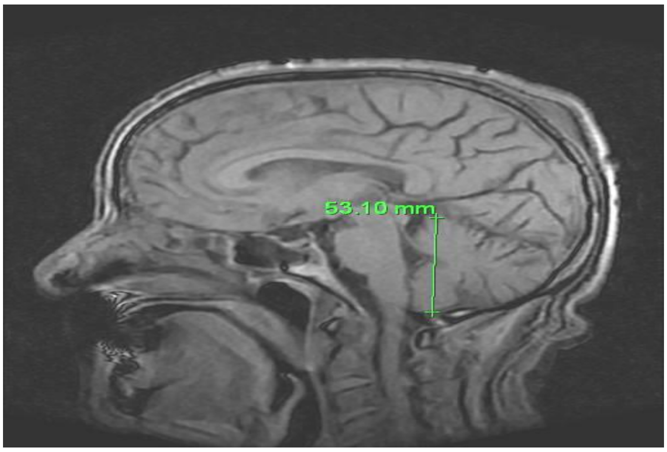

Figure No (3-7): Shows The crinocaudally or height of cerebellum in sagittal image

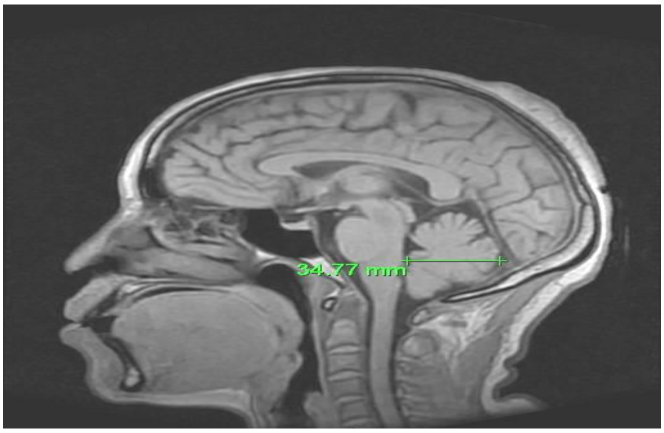

Figure No (3-8): Shows The AP width of cerebellum measurement at sagittal image

3.2.2.1.3Coronal Image:

3.2.2.1. 3.1 Maximum Cerebellum Measurement in coronal planes:

The image was selected till it was reached the cerebellum view at base of skull where the lateral ventricle was appeared then the creaser was positioned at the more top and upper point in the inner border then it was traced till reach the lower bottom end in the inner border and this measuring was called maximum cerebellum length at coronal image .Then the creaser was positioned at more wider parts on the RT side and it was traced till reach the symmetrical point in the opposite LT side , and that measurement was called maximum cerebellum width at coronal image .

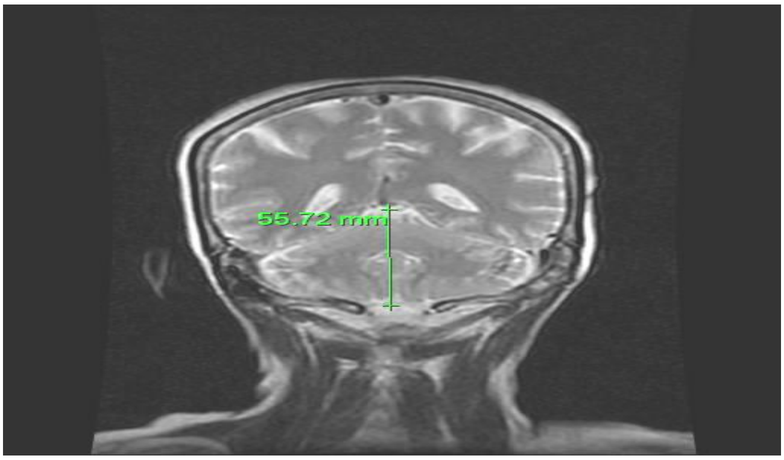

Figure No (3-9): Shows The maximum length measure of cerebellum at coronal plane FSE T2 weighted image

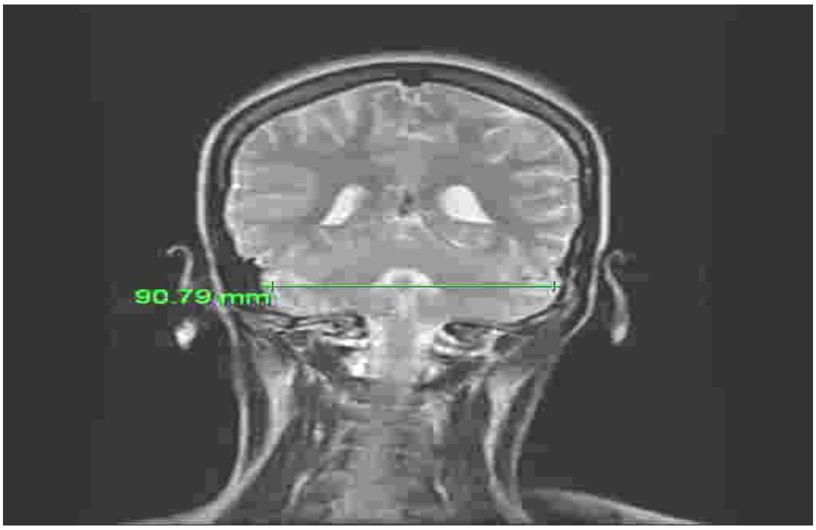

Figure No (3-10): Shows The maximum measure of cerebellum width at coronal plane FSE T2 weighted image

3.2.2.1.3.2 Coronal measurement of the cerebellum for each hemisphere:

The image was chosen till reach the cerebellum view at base of skull and the creaser was positioned at the more top and upper point in RT hemisphere of cerebellum then it was drawn till reach lower bottom area at another side along RT hemisphere the reading was taken which called RT hemisphere length of cerebellum at coronal image, then the creaser was transferred to the second side in LT hemisphere and the creaser was positioned in middle inner border and it was drawn till reach the lower bottom end ,then the measurement of the length of LT cerebellum hemisphere was taken which called LT cerebellum hemisphere at coronal image , then the creaser was transferred to inner border of RT hemisphere at the middle of right surface at more wider area and it was traced till reach the mid line of cerebellum and this reading was taken which called RT hemisphere width of cerebellum at coronal image ,after that the creaser was turned at the more wider point in inner border of LT hemisphere of left side of cerebellum, then it was drawn till mid line and measurement was taken which called LT hemisphere width of cerebellum at coronal image.

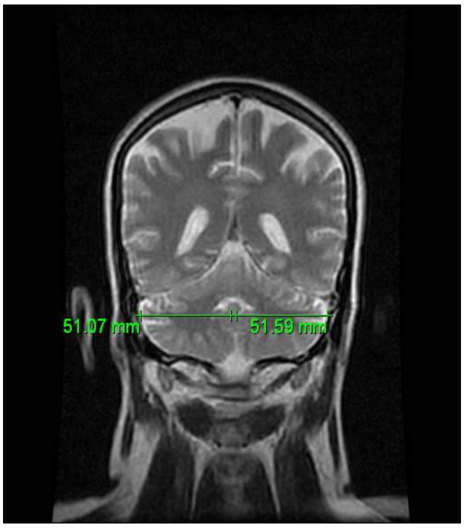

Figure No (3-11): Describe The coronal cerebellum measure width for each hemispher T2 weighted image

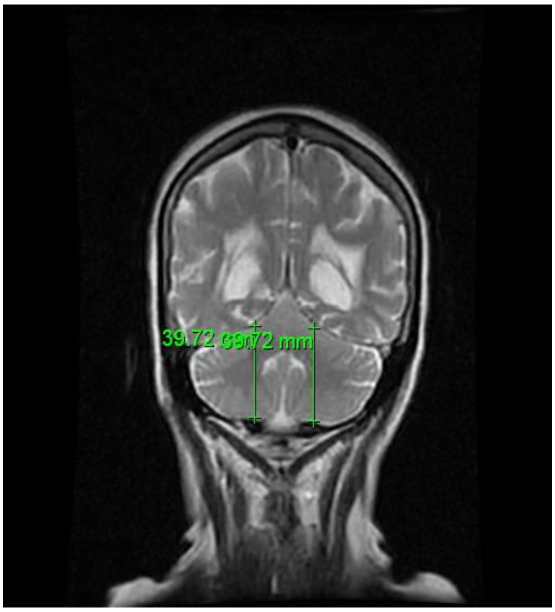

Figure No (3-12): Describe The coronal cerebellum measure length for each hemisphereT2 weighted image

3.2.2.1. 3.2 Coronal cerebrum:

3.2.2.1. 3.2 .1 Maximum cerebrum measurement in coronal plane:

Then at same level where the lateral ventricle was appeared the creaser was positioned at The upper inner border at mid line between the lateral ventricle horns , then it was drawn till to lower part then the reading was taken which was called the general length of cerebrum at coronal plane , then the creaser was positioned till more the wider point on RT side and then creaser was traced till reach the LT symmetrical point in opposite direction , the reading was taken which was called the maximum cerebrum width at coronal plane .

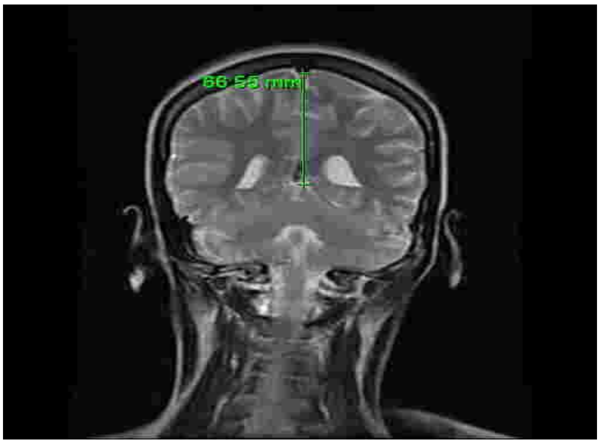

Figure No (3-13): Describe The coronal measure of maximum cerebrum lengthT2 weighted image

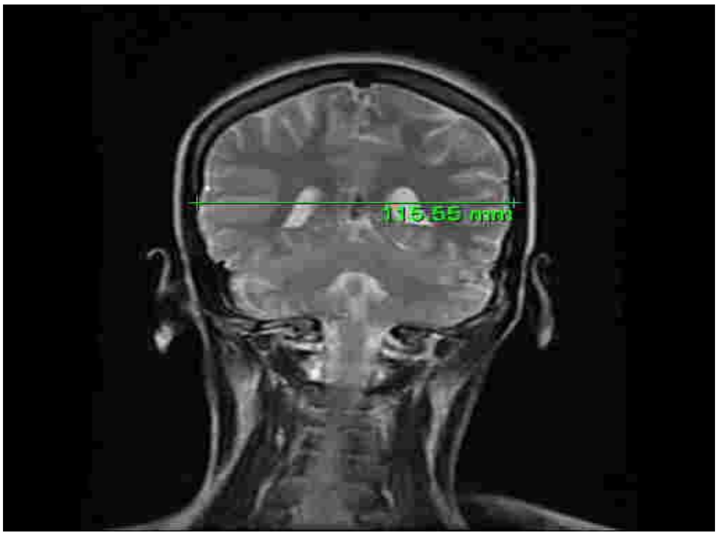

Figure No (3-14): Describe The coronal measure of maximum cerebrum widthT2 weighted image

3.2.2.1.3.2.2 Coronal Cerebrum measurement for each hemisphere:

The image was selected when the level of the lateral ventricle was appeared , the creaser was positioned at first in the inner upper border of the RT hemisphere of brain then it was traced till reach the inner lower bottom ,then the measurement line was passed through the lateral ventricle horn , the reading was taken which was called RT hemisphere length of cerebrum at coronal plane , then the creaser was transferred to the second side in LT hemisphere of cerebrum in middle of inner upper border and it was drawn till it was reached the lower inner bottom border the reading was taken which was called LT hemisphere Length of cerebrum at coronal image plane , then the creaser was transferred in to inner border of the RT hemisphere at the middle of left surface at more width area and drawn it till the creaser was reached the mid line of cerebrum and this reading was called the RT hemisphere width of cerebrum at coronal image ,after that creaser was turned at the more point width in inner border of RT surface of left side of cerebrum then take it till the mid line and the measurement was taken which was called the LT hemisphere width of cerebrum at coronal image .

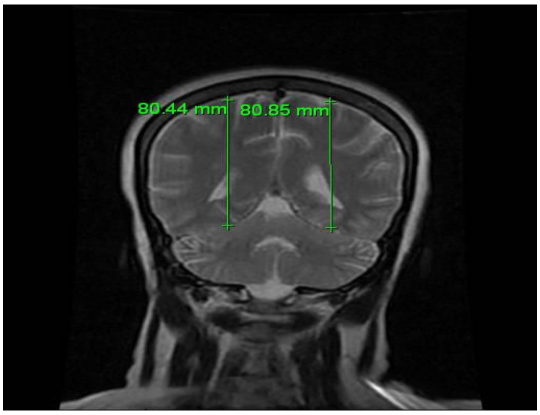

Figure No (3-15):Describe The measuremnt of cerebrum hemispheres length at coronal T2 weighted image flair

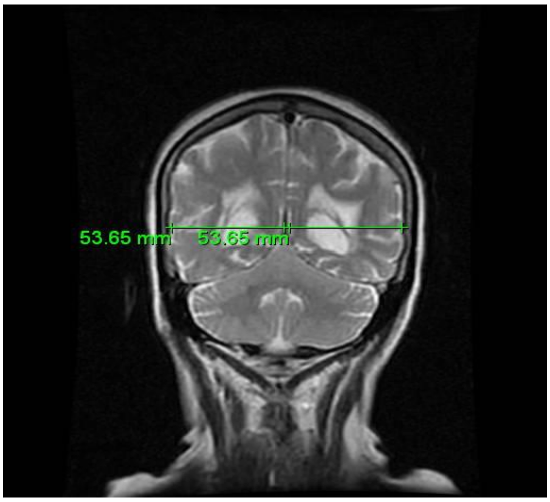

Figure No (3-16): Describe The measuremnt of cerebrum hemispheres width at coronal T2 weighted image with flair

3.2.2.2 Method of Cerebellum Volume measurement:

In this measurement using program which was called wolform mathmatica which was advanced software, which using for Image analysis, interpretation and applications.

3.2.2.2 .1 Introduction about Wolform Mathmatica:

Wolfram Mathematica is a robust software development for doing mathematics and calculations. It has wide spread applications in different fields and is often used for research, loading and analyzing data, giving technical presentations and seminars etc. Mathematica is extraordinary well rounded. It is suitable for both numeric and symbolic work. Mathematica was first published by Wolfram Research in 1988 and the latest version, 5.0, was released during summer 2003. This program using versions of Mathematica ranging from4.1 through 5.0, and care has been taken to ensure that the examples will work with both version 5.0 and it is immediate. Predecessor, version 4.2. Version 11.0 is available for Windows 98/Me/NT 4.0/2000/XP and several versions of the Unix (including Macintosh OS X) and Linux operating systems. Many functions in the Wolfram Language work on images. It's easy to get an image into the Wolfram Language, for example by copying or dragging it from the web or from a photo collection. Can also just capture an image directly from the camera and using the function Current Image. (Santanu ,K. Maiti .etal. 2006)

3.2.2.2.3 How the Wolfram Mathematic Program Measure the cerebellum Volume and vermeil area:

It is software program me using for many application in the MRI image firstly obtain the third dimenation for any image , calculate the volume and any specific square area that was tasked were achievable, by using variable equations to control in MRI image , first one called (image adjust) which control image contrast by union the color of image in to two colors white and black to be easy classify between colors if there any problem could be distinguished with other color ,the white color been more whiter which represent the white matter of the cerebellum image , the black color which represent the gray matter of the cerebellum image was appeared more black as it clear in appendix(b-1) ,the second applied equation was called (image apply) and advantage of this equation it was removed any distortion in the image, then magnify the pixel edges to calculate easily the square areas as appear in appendix (b-2) and the most useful applicable of this program that it could calculated the image square of areas that lie between the gaps of slices and calculate the sum of them ,which help to have real reading, then the program was calculated any square areas to get the volume of cerebellum as explained in appendix (b-3) ,for account the area square division on `10 to transfer the calculating area from mm to cm2 but in volume division on 100 to turn to cm3 (Santanu K. Maiti etal 2006).

The following diagram explain the steps of MRI image after import in wolform mathematic program:

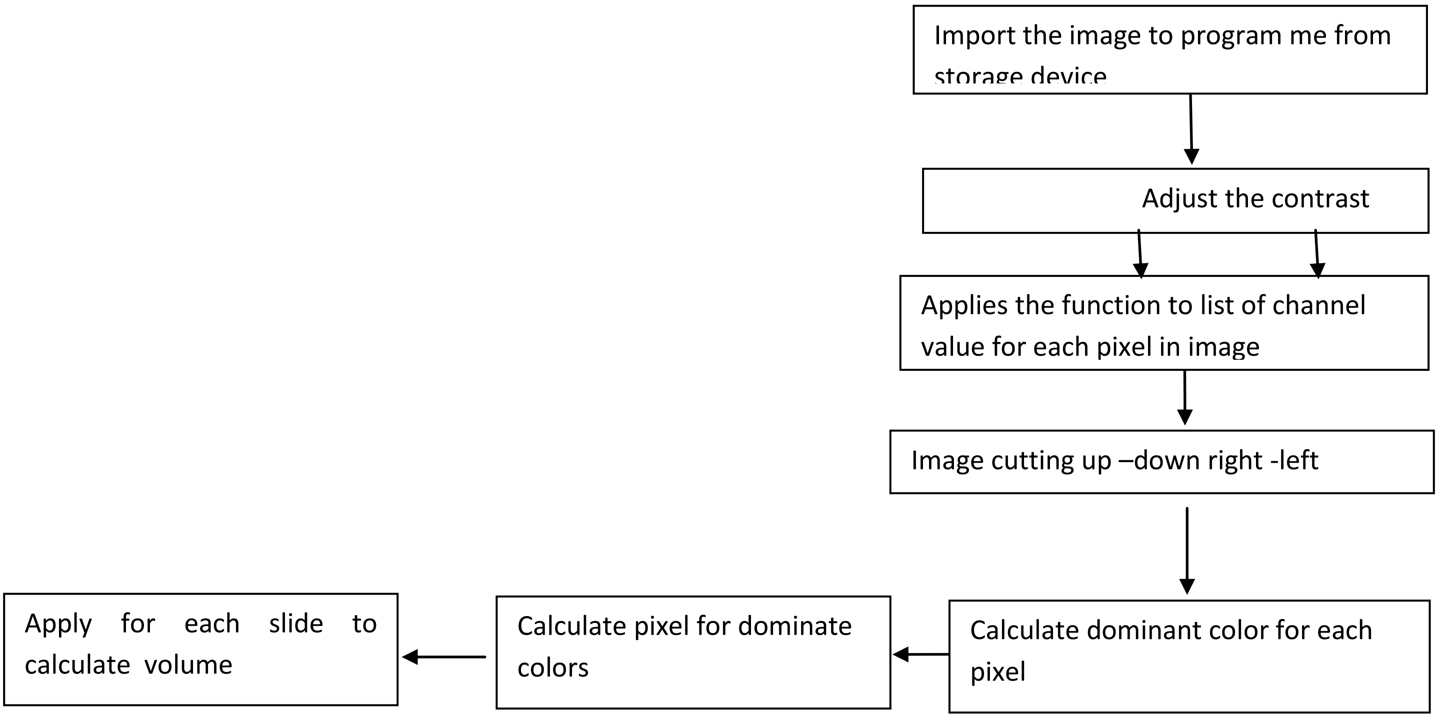

Figure No (3- 17): Diagram illustration how the wolfrom mathematical program me calculate the volume and vermin area from MRI image (Santanu K. Maiti etal 2006)

3.3Tools:

3.3.1 Data collection:

Use data collection sheet

3.3.2 Data analysis :

Using spss program me all values of variables expressed as means ±SD ,maximum ,minimum value ,T-Test use to compare means and P-value of <0.05 was considered to be statically significant ,ANOVA (analysis of avariance),Graphic including linear relationship and pie graph were used , Microsoft EXCEL and statistical package for social science SPSS under windows.

3.3.3 Data presentation:

Present on tables and figures.

3.4 limitation of the study:

The proposed numbered in this study was 200 participants , the first 100 participants were scanned and the valuable including surface measurements were done .However some of the measurements including the vermin area and volume of cerebellum were obtained at the same time , in the advanced stage in research this data was lost and another group of participants were selected to be able to measurement the volume and vermin area of cerebellum with same age range of the first group , to have a real reading and more accurate ,general and standard study .

3.5 Ethical concern:

Verbal consent was taken from hospital administer and patients ,no identification or individual details were published no information or patient details will be disclosed or used for other than this study

Chapter Four
The Result

Chapter Four

The Result

The Result:

This study was performed on 200 participants .The Sample was divided into two groups .The first group included 100 participants where the linear measurements were taken (For Cerebellum: in Axial scan length and width for each hemisphere as well as, maximum width and maximum length .In Coronal plane: length and width for each hemisphere as well as, maximum width and maximum length. In Sagittal AP diameter and cerebellum width. For Cerebrum: in Axial scan length and width for each hemisphere as well as, maximum width and maximum length .In Coronal plane: length and width for each hemisphere as well as, maximum width and maximum length)

The second group included another 100 participants where the Cerebellum volume and vermian area were measured as follow:

Results of Group one:

Table No (4-1): Descriptive statistics of the sample group one classified according to gender presented as frequency and percentage :

Gender	Frequency	percentage%
Male	39	39%
Female	61	61%
Total	100	100%

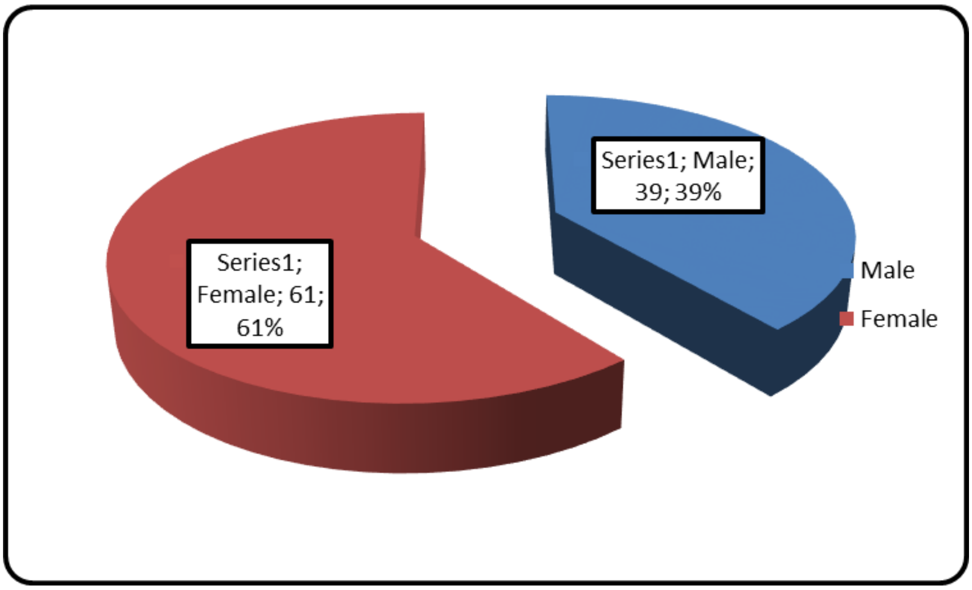

Figure No (4-1): Distribution of study sample according to Gender group one:

Table No (4-2) Distribution of study sample group one according to Age classified into frequency and percentage:

Age /years	frequency	percentage
14 - 24	19	19%
25 -34	14	14%
35 -44	23	23%
45 -54	20	20%
55-64	10	10%
>65	14	14%
Total	100	100%

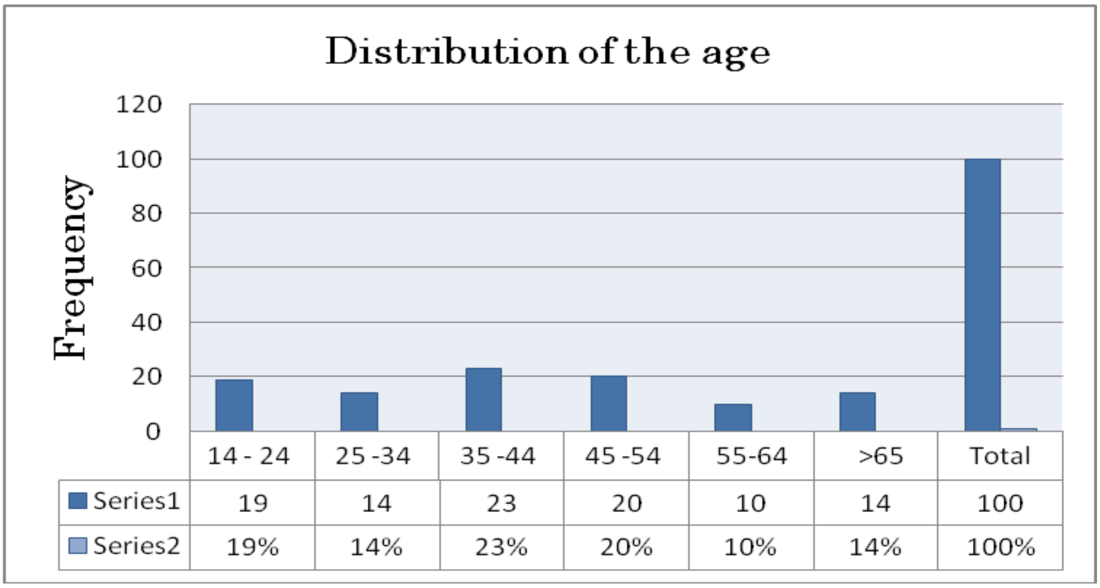

Figure No (4-2): Distribution of study sample according to Age class in group one:

Table No (4-3): Descriptive statistics of cerebellum and cerebrum linear measurements in axial and sagittal planes group one:

Anatomical part/plane (n=100)	Min (mm)	Max (mm)	Mean (mm)	STDV
Cerebellum hemispheric maximum width –axial	64.29	114.76	93.54	7.70
Cerebellum height -Sagittal	37.23	70.52	47.01	4.40
Cerebellum vermis AP width -sagittal	27.78	441.98	41.83	41.17
Cerebrum maximum length-axial	111.91	175.89	157.42	8.53
Cerebrum maximum width –axial	108.44	146.20	120.75	5.44

Table No (4-4): descriptive statistics of the measured cerebellum hemisphere maximum width ,height ,cerebellum vermis AP width and cerebrum length and width classified according to age class in group one:

Anatomical part	Age class	N	Mean	Std. Deviation	Minimum	Maximum	P-value
Cerebellum hemisphere maximum Width-Axial	14-24	19	92.29	8.43	64.29	102.45	.729
	25-34	14	94.16	5.75	84.76	108.16	
	35-44	23	95.00	6.63	79.86	106.24	
	45-54	20	92.60	6.74	71.01	108.12	
	55-64	10	91.54	12.38	67.07	104.37	
	65+	14	94.98	7.73	87.14	114.76	
	Total	100	93.54	7.70	64.29	114.76	
Cerebellum height - Sagittal	14-24	19	46.40	4.07	38.69	52.62	.387
	25-34	14	46.87	3.33	41.20	51.10	
	35-44	23	46.37	4.58	37.23	61.03	
	45-54	20	49.00	6.15	42.66	70.52	
	55-64	10	46.98	3.35	40.96	50.22	
	65+	14	46.19	3.30	39.67	50.75	
	Total	100	47.01	4.46	37.23	70.52	
Cerebellum vermis AP Width- Sagittal	14-24	19	37.92	4.51	30.26	45.66	.386
	25-34	14	39.31	7.13	32.25	53.80	
	35-44	23	36.97	4.30	27.78	44.87	
	45-54	20	60.60	90.91	29.78	441.98	
	55-64	10	36.44	3.38	30.26	40.10	
	65+	14	34.69	4.58	27.78	45.21	
	Total	100	41.83	41.17	27.78	441.98	
Cerebrum Length - Axial	14-24	19	157.57	6.88	142.33	175.89	.004
	25-34	14	165.57	4.98	157.83	173.90	
	35-44	23	155.92	6.55	142.38	171.91	
	45-54	20	156.64	8.37	139.31	167.84	
	55-64	10	155.68	16.14	111.91	167.63	
	65+	14	153.83	3.956	146.71	162.39	
	Total	100	157.41	8.53	111.91	175.89	
Cerebrum Width - Axial	14-24	19	119.58	5.79	109.49	129.55	.319
	25-34	14	121.51	5.27	111.19	127.25	
	35-44	23	120.80	4.42	113.79	129.59	
	45-54	20	120.41	4.60	108.44	129.44	
	55-64	10	124.17	8.74	113.81	146.20	
	65+	14	119.51	4.61	113.96	127.64	
	Total	100	120.75	5.44	108.44	146.20	

Table No (4-5): Descriptive statistics of the measured cerebellum hemisphere maximum width ,height , cerebellum vermis AP Width and cerebrum length and width classified according to gender:

Anatomical part/plane (n=100)	**Gender**	**number**	**mean (mm)**	**STDV**	**p-value**
Cerebellum hemispheric maximum width –axial	Male	39	95.51	8.98	0.040
	Female	61	92.28	6.53	
Cerebellum height- Sagittal	Male	39	46.97	4.39	.705
	Female	61	47.14	4.53	
Cerebellum vermis AP width –sagittal	Male	39	46.88	65.16	.330
	Female	61	38.61	8.98	
Cerebrum length-axial	Male	39	160.37	7.41	.005
	Female	61	155.52	8.71	
Cerebrum width –axial	Male	39	121.48	4.66	2.83
	Female	61	120.28	5.88	

Table No (4-6): Describe the linear measurements of cerebellum length and width for each hemisphere in axial and coronal planes in group one:

Anatomical Structure/plane	**Anatomic part**	**Mean ±SD(mm)**
cerebellum hemisphere length in axial plane	RT hemisphere	61.5±6.37
	LT hemisphere	61.4±5.91
cerebellum hemisphere length in coronal plane	RT hemisphere	38.4±4.77
	LT hemisphere	38.4±4.77
cerebellum hemisphere width in axial plane	RT hemisphere	47.1±3.26
	LT hemisphere	47.1±3.42
cerebellum hemisphere width in coronal plane	RT hemisphere	48.5±6.06
	LT hemisphere	48.5±6.06

Table No (4-7): Describe the linear measurements of cerebrum length and width for each hemisphere in axial and coronal planes in group one:

Anatomical plane	**Anatomic part**	**Mean ±SD(mm)**
cerebrum hemisphere length in axial plane	RT hemisphere	**152.3±6.73**
	LT hemisphere	**151.4±14.8**
cerebrum hemisphere length in coronal plane	RT hemisphere	**77.5±10.46**
	LT hemisphere	**77.5±10.46**
cerebrum hemisphere width in axial plane	RT hemisphere	**58.6±3.24**
	LT hemisphere	**58.6±3.24**
cerebrum hemisphere width in coronal plane	RT hemisphere	**58.2±4.34**
	LT hemisphere	**58.2±4.34**

Table No (4-8): Describe the linear measurements of cerebrum and cerebellum maximum width in axial and coronal planes in group one:

Anatomical plane	Anatomic part	Mean ±SD(mm)
maximum cerebellum length	Axial plane	122.9±12.11
	Coronal plane	76.8±9.23
maximum cerebellum width	Axial plane	94.2± 6.64
	Coronal plane	96.9± 9.97`
maximum cerebrum length	Axial plane	157.42±8.53
	Coronal plane	156.11±6.33
maximum cerebrum width	Axial plane	120.75± 5.42
	Coronal plane	119.4±7.23

Table No (4-9): Correlation between the RT Cerebellum hemisphere length &RT Cerebrum hemisphere length in Axial and Coronal planes:

Plane	***Anatomical Structure/site***	***Mean(SD)(mm)***	***P- Value***
Axial	***RT Cerebellum hemisphere Length***	61.5±6.37	**0.000****
	RT Cerebrum hemisphere Length	152.3±6.73	
Axial	***RT Cerebellum hemisphere Width***	47.1±3.26	**0.000****
	RT Cerebrum hemisphere Width	58.6±3.24	
Coronal	***RT Cerebellum hemisphere Length***	38.4±4.77	**0.000****
	RT Cerebrum hemisphere Length	77.5±10.46	
Coronal	***RT Cerebellum hemisphere Width***	48.5±6.06	**0.000****
	RT Cerebrum hemisphere Width	58.2±4.34	

Table No (4-10): Correlation between the LT Cerebellum hemisphere length &LT Cerebrum hemisphere length in Axial and Coronal planes:

Plane	***Anatomical Structure/site***	***Mean(SD)(mm)***	***P- Value***
Axial	***LT Cerebellum hemisphere Length***	**61.4±5.91**	**0.000****
	LT Cerebrum hemisphere Length	**151.4±14.8**	
Axial	***LT Cerebellum hemisphere Width***	**47.1±3.42**	**0.000****
	LT Cerebrum hemisphere Width	**58.6±3.24**	
Coronal	***LT Cerebellum hemisphere Length***	**38.4±4.77**	**0.000****
	LT Cerebrum hemisphere Length	**77.5±10.46**	
Coronal	***LT Cerebellum hemisphere Width***	**48.5±6.06**	**0.000****
	LT Cerebrum hemisphere Width	**58.2±4.34**	

***Relations between the cerebellum and cerebrum hemispheres length and width in both axial and coronal planes:**

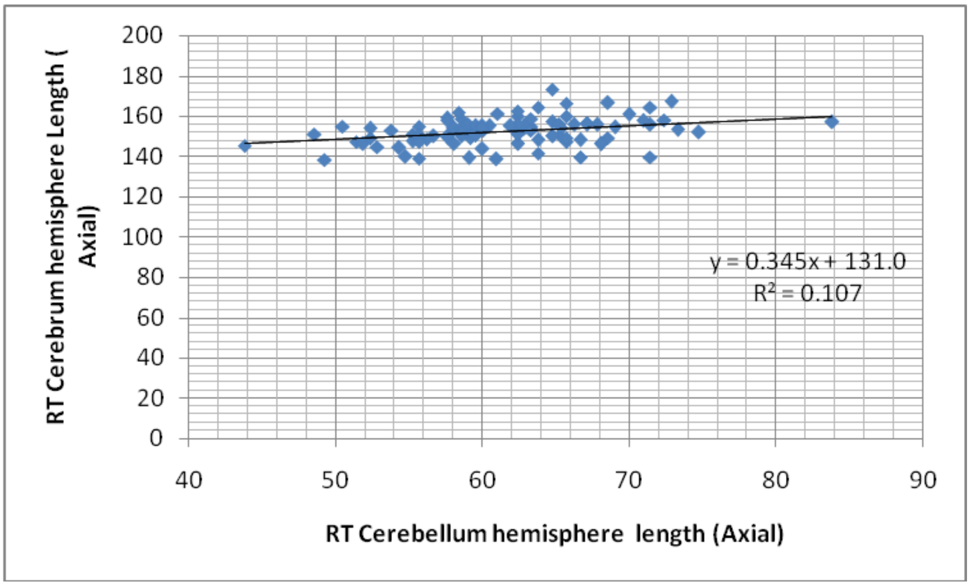

Figure No (4-3): Shows The Relation between the RT Cerebellum hemisphere length &RT Cerebrum hemisphere length in axial plane

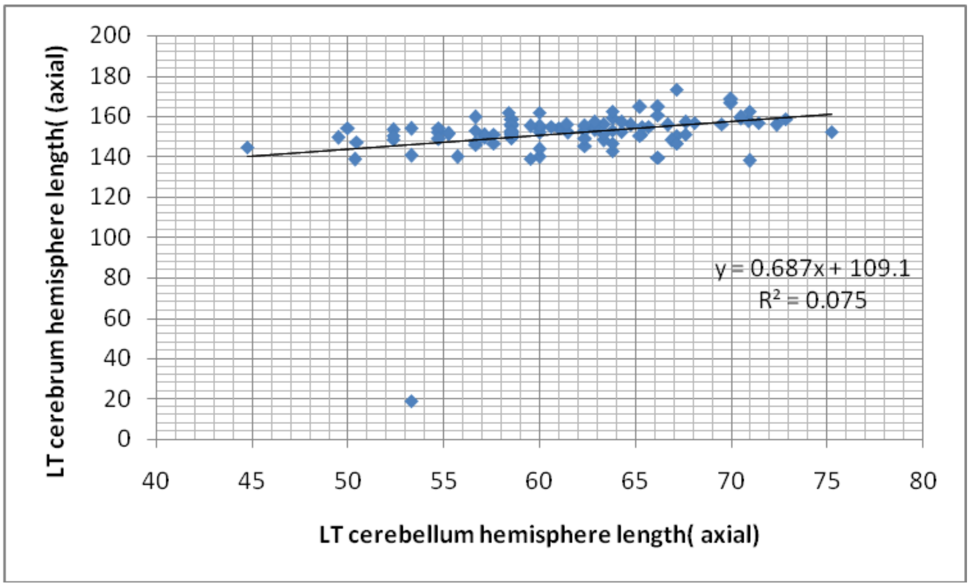

Figure No (4-4): Shows The Relation between the LT Cerebellum hemisphere length &LT Cerebrum hemisphere length in axial plane

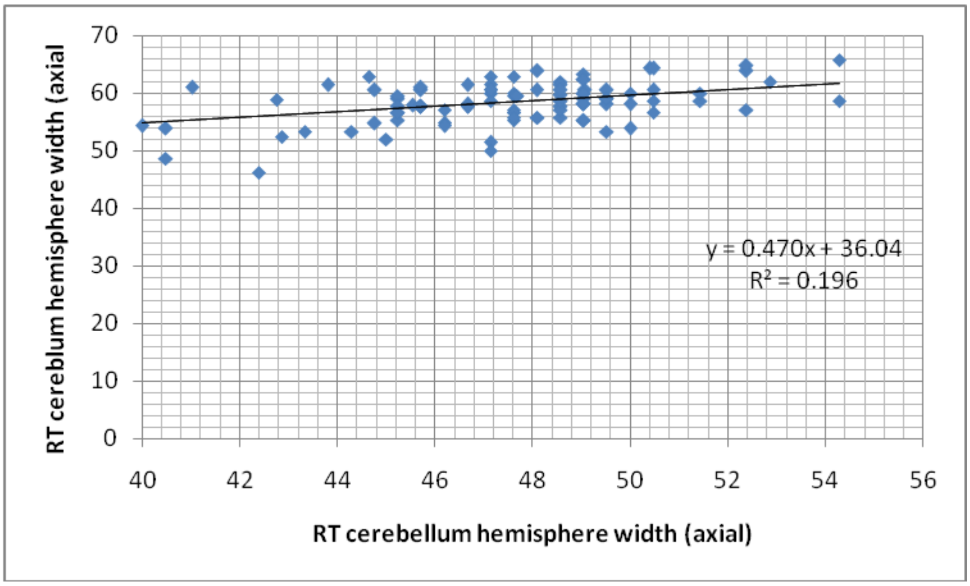

Figure No (4-5): Shows The Relation between the RT Cerebellum hemisphere width &RT Cerebrum hemisphere width in axial plane

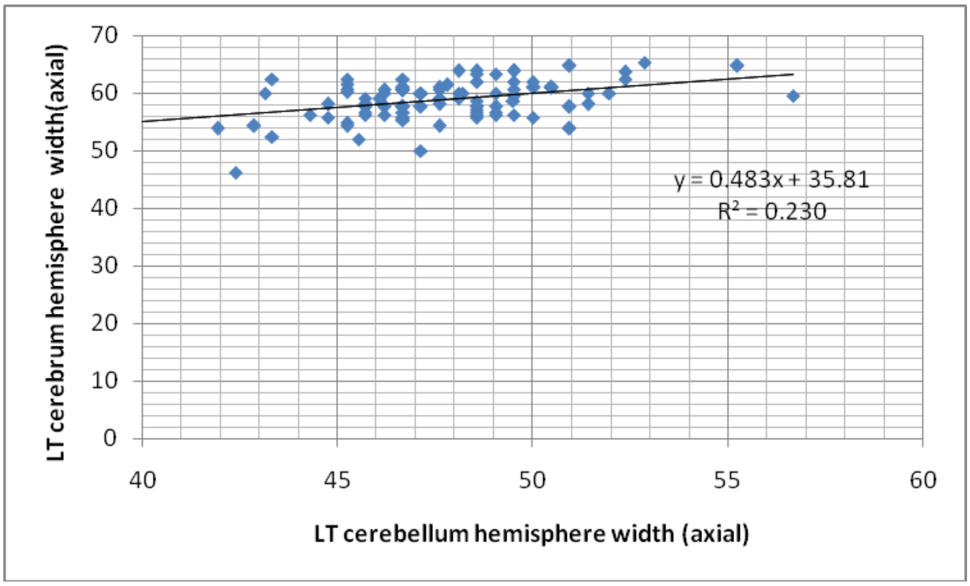

Figure No (4-6): Shows The Relation between the LT Cerebellum hemisphere width &RT Cerebrum hemisphere width in axial plane

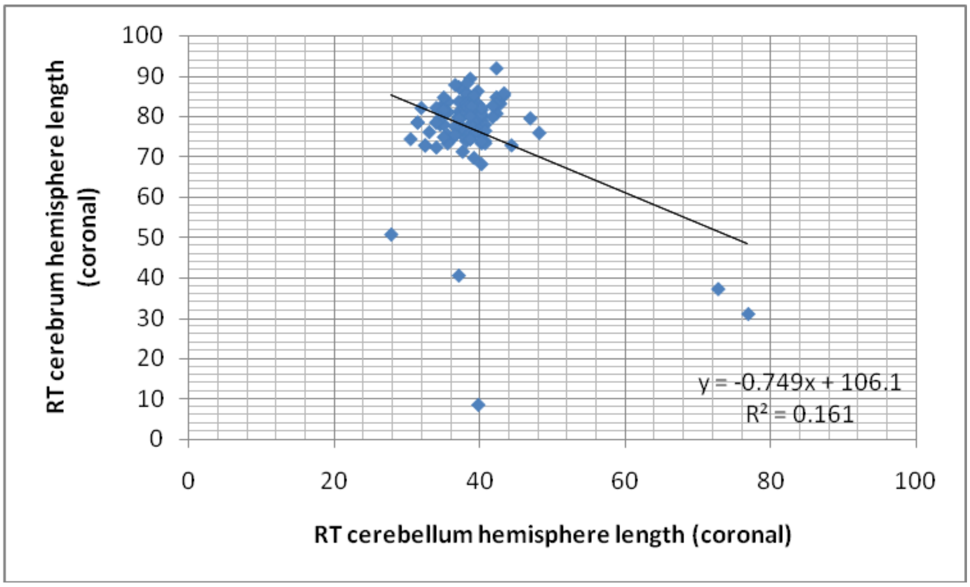

Figure No (4-7): Shows The Relation between the RT Cerebellum hemisphere length &RT Cerebrum hemisphere length in coronal plane

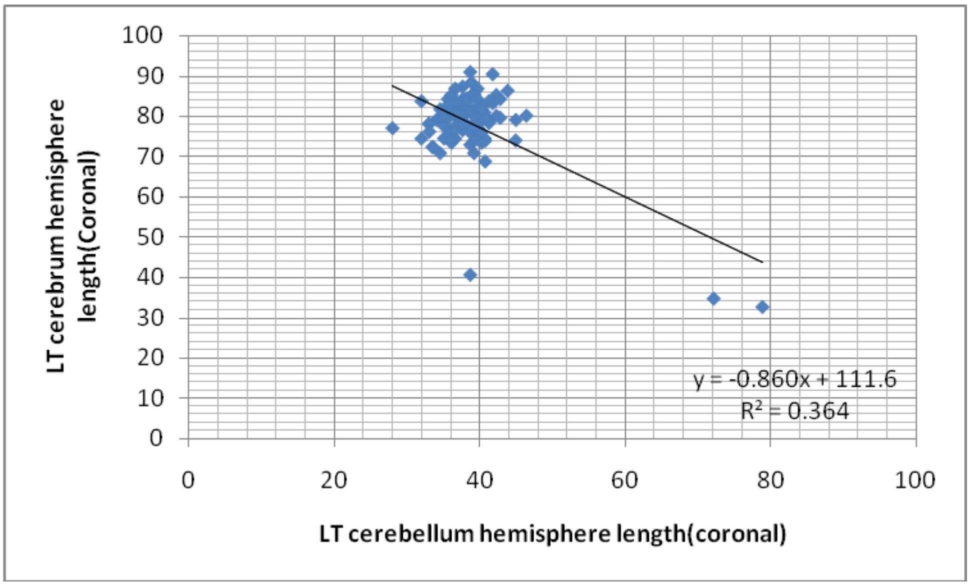

Figure No (4-8): ShowsThe Relation between the LT Cerebellum hemisphere length &LT Cerebrum hemisphere length in coronal plane

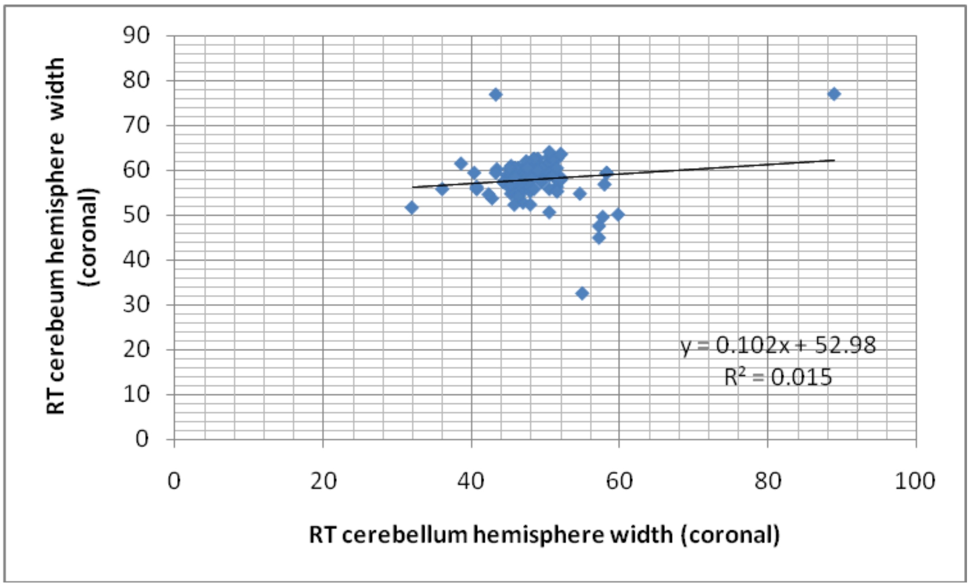

Figure No (4-9): Shows The Relation between the RT Cerebellum hemisphere width &RT Cerebrum hemisphere width in coronal planes

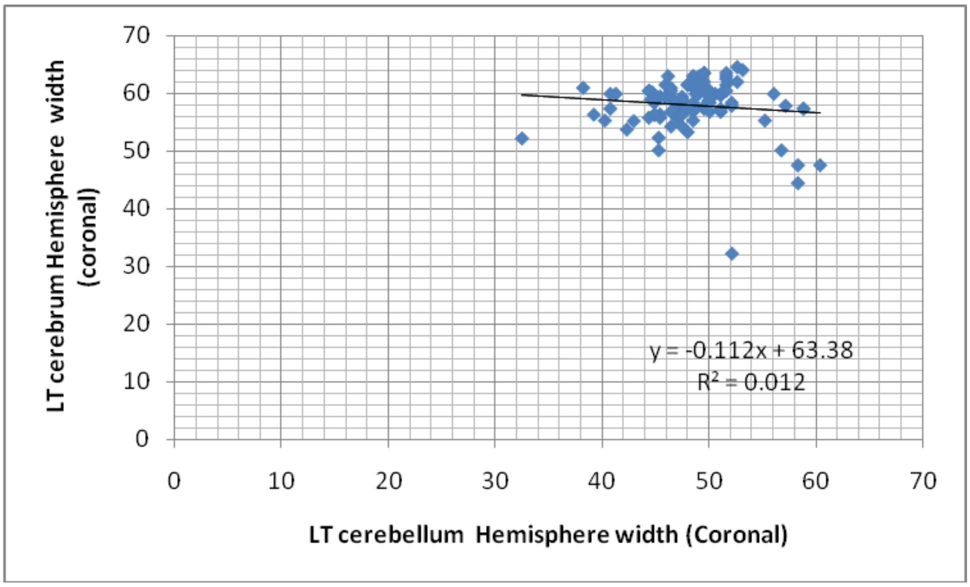

Figure No (4-10): Shows The Relation between the LT Cerebellum hemisphere width &LT Cerebrum hemisphere width in coronal planes

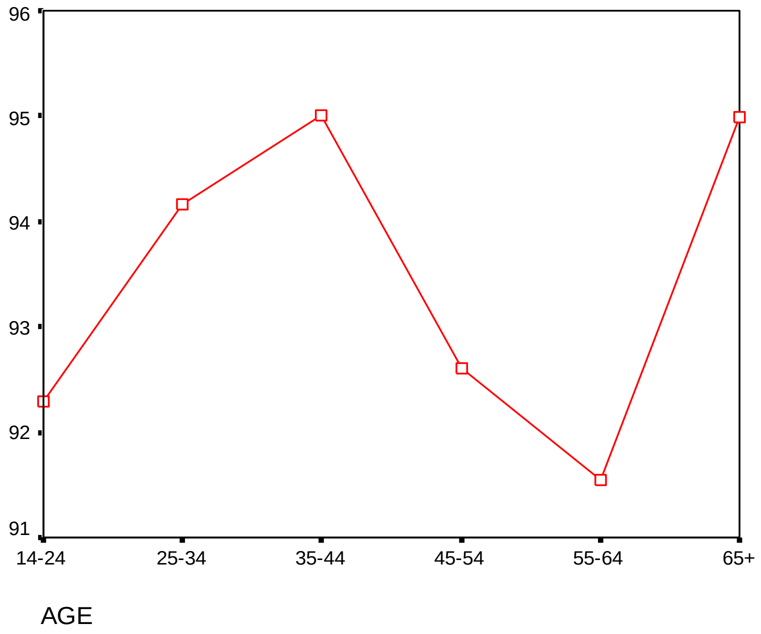

Figure No (4-11): Shows The distribution of the cerebellum maximum width through age class measured in axial plane

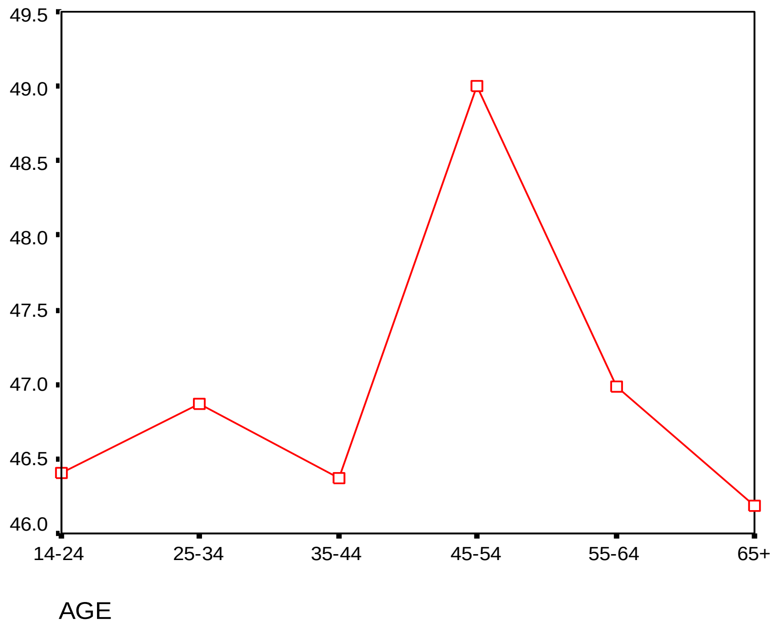

Figure No (4-12): Shows The distribution of the cerebellum maximum length through age class measured in sagittal plane

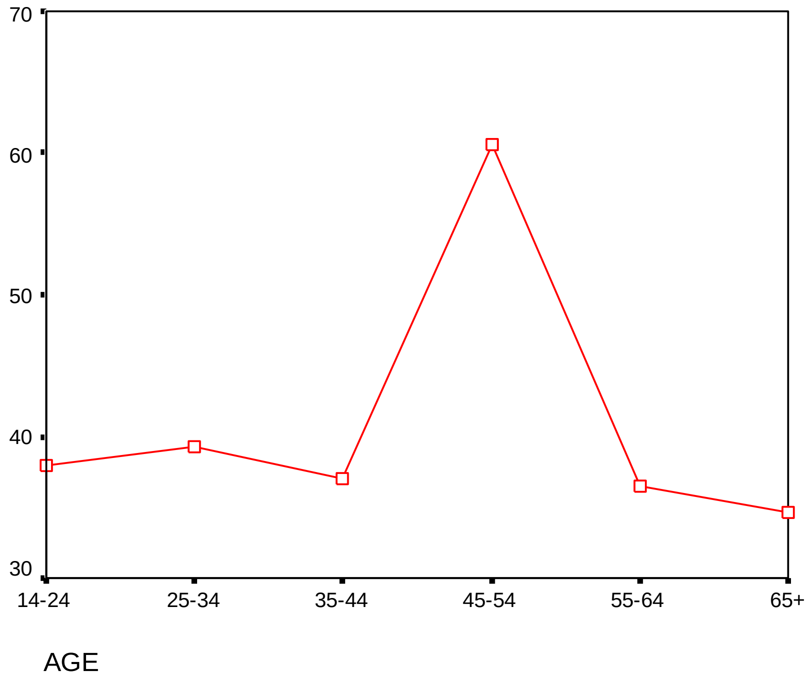

Figure No (4-13): Shows The distribution of the cerebellum maximum width through age class measured in sagittal plane

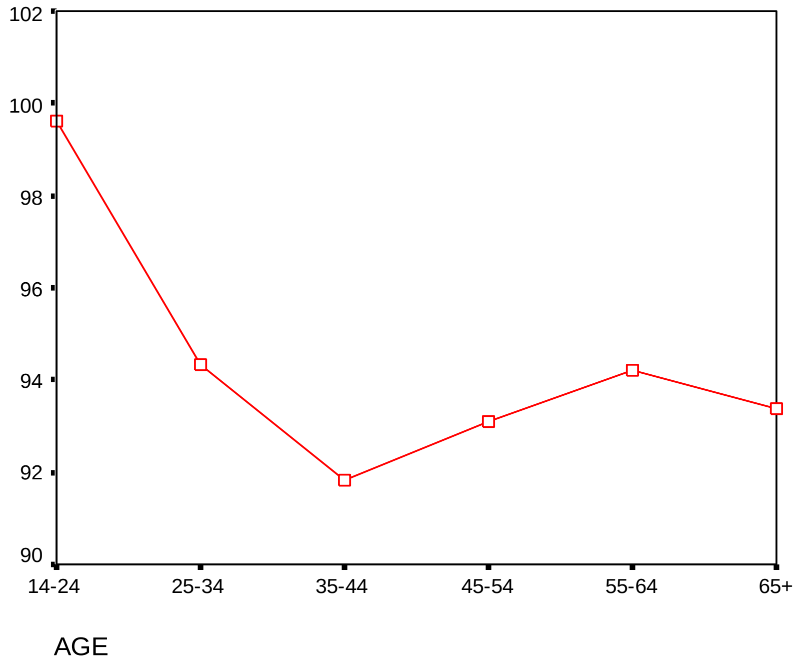

Figure No (4-14): Shows The distribution of the cerebellum maximum width through age class measured in coronal plane

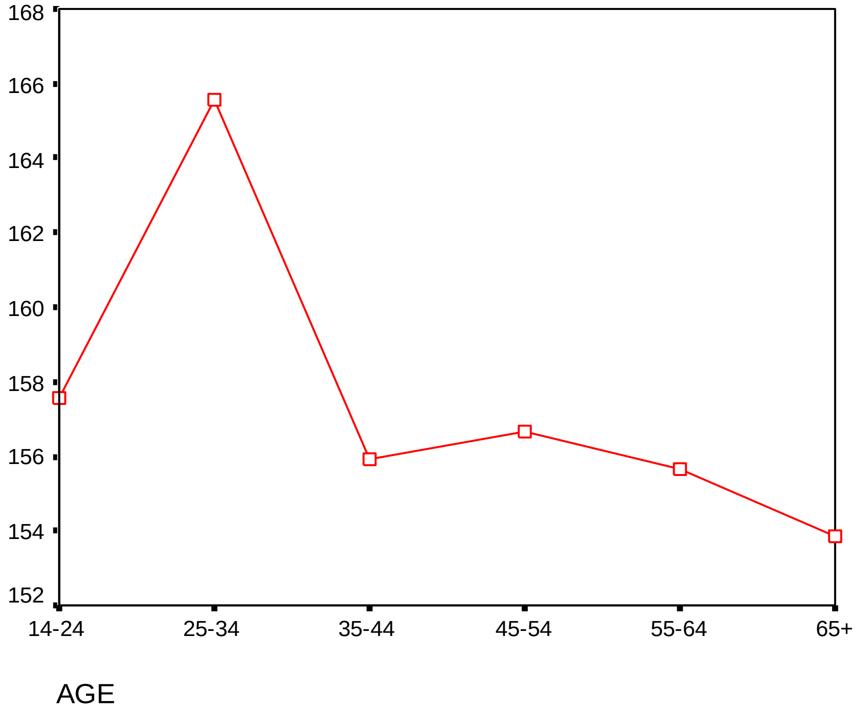

Figure No (4-15): Shows The distribution of the cerebrum maximum length through age class measured in axial plane

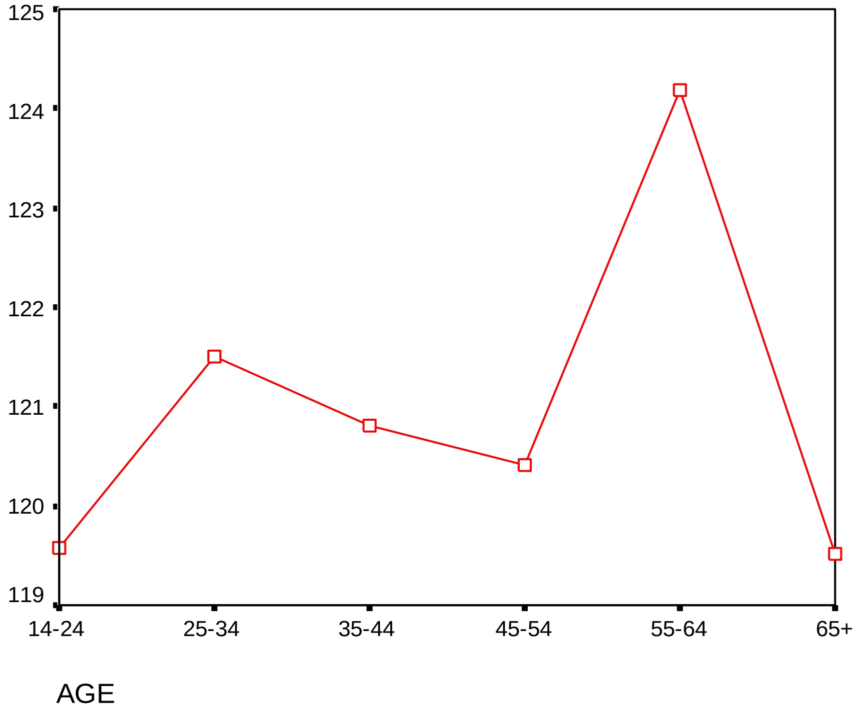

Figure No (4-16): Shows The distribution of the cerebrum maximum width through age class measured in axial plane

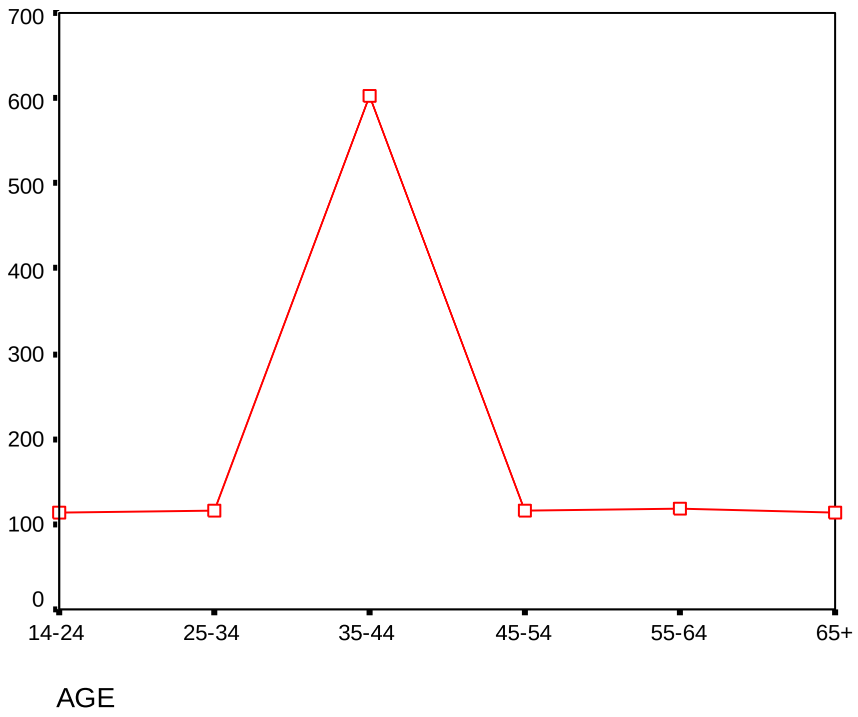

Figure No (4-17): Shows The distribution of the cerebrum maximum width through age class measured in coronal plane

Group two:

Table No (4-11): Descriptive statistic of gender presented as frequency and percentage in group two:

Gender	frequency	Percentage %
Male	41	41%
Female	59	59%
Total	100	100%

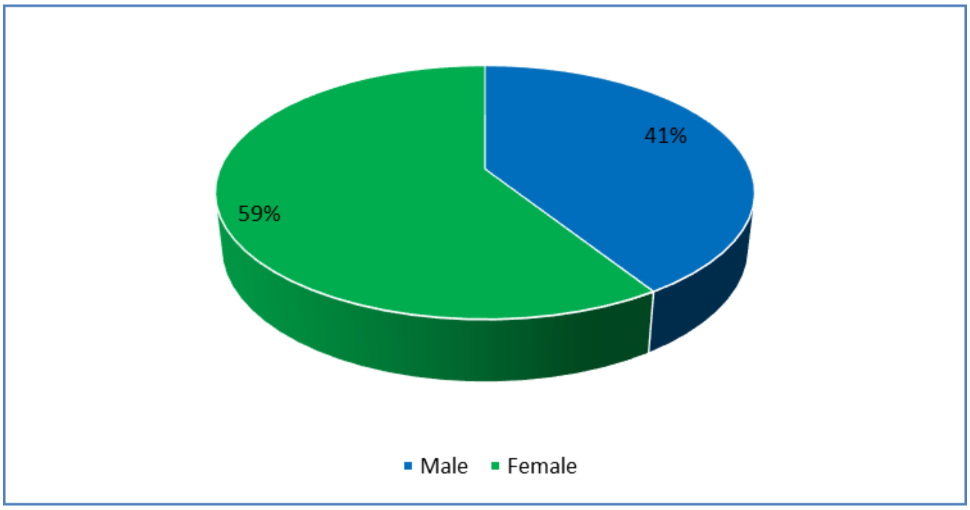

Figure No (4-18): Describe the distribution of the sample according to gender in group two:

Table No (4-12): Descriptive statistics of age class ,frequency and percentage in group two:

Age Classification	frequency	Percentage %
14 - 30 year	27	27%
31 -46 year	29	29%
47 -63 year	28	28%
64 - 80 year	16	16%
Total	100	100%

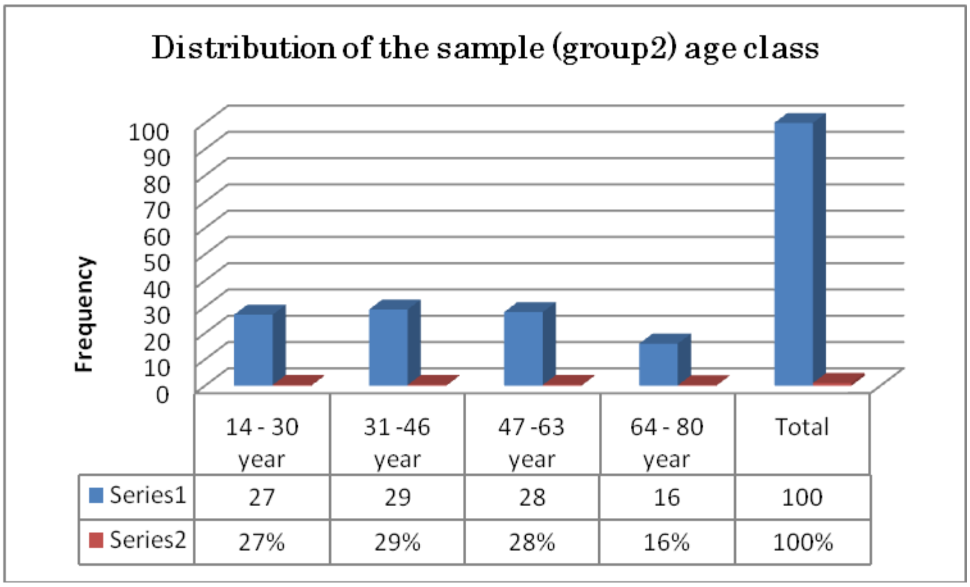

Figure No (4-19): Describe the distribution of sample in age classes in group two:

Table No (4-13):Describe the Correlation between the cerebellum volume , Age and p-value group two:

Age class	Mean(SD)	P- Value
14 -30 year	193.2±24.81	0.672
31 - 46 year	190.9±17.03	
47 - 63 year	186.5±19.58	
64 - 80 year	192.8±26.88	

** Significant at 0.01 Level

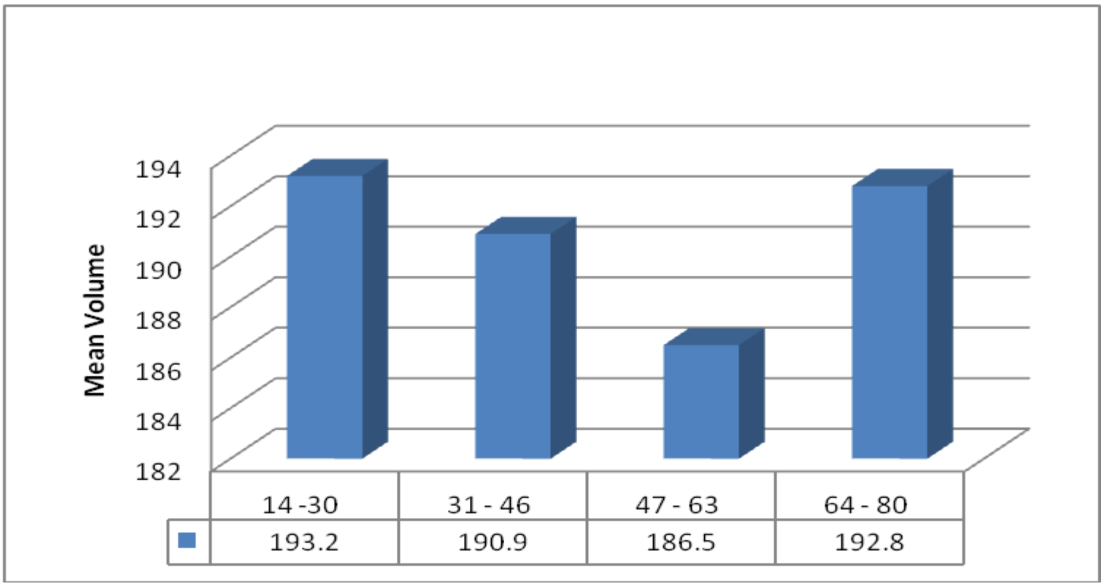

Figure No (4-20): Shows The distribution of cerebellum mean volume through the age classes in group two:

Table No (4-14): Describe Correlation of mean of cerebellum volume for both genders and p-value in group two:

Gender	Mean(SD)cm^3	P- Value
Female	184.1±19.22	.000**
Male	199.9±21.57	

** Significant at 0.01 Level

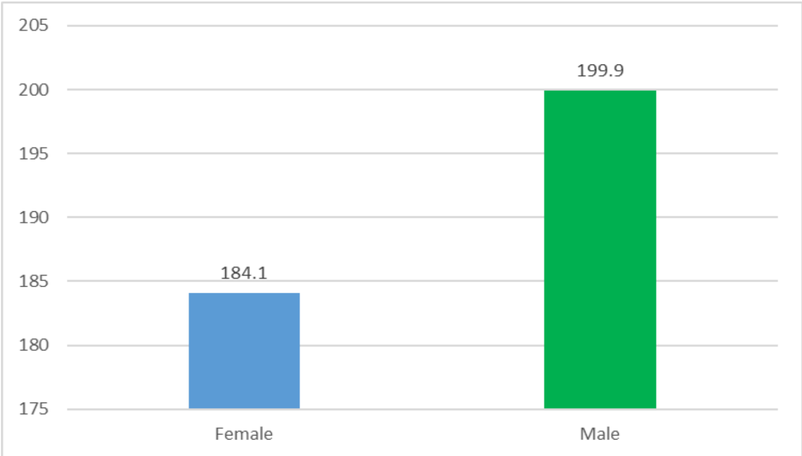

Figure No (4- 21) :Shows The distribution of the mean of cerebellum volume for both gender in group two:

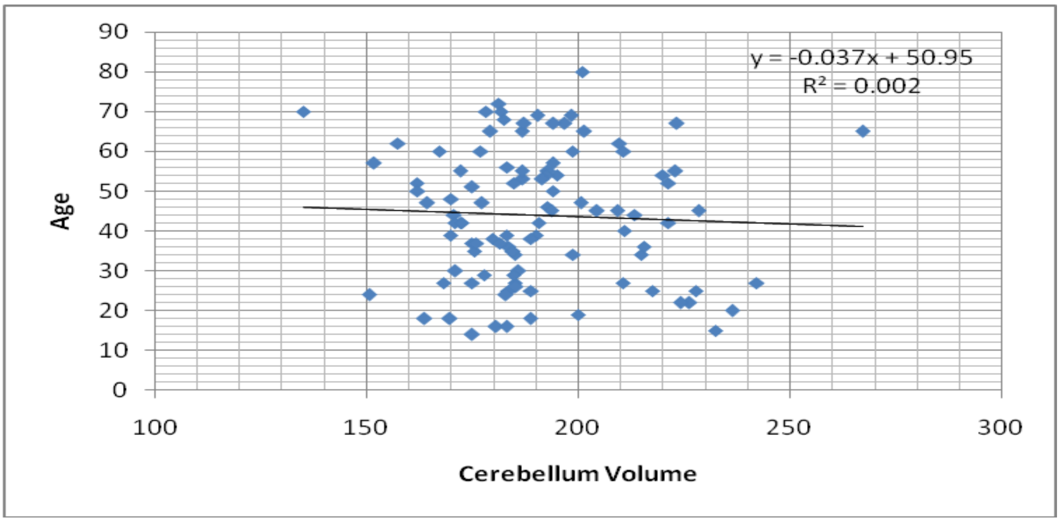

Figure No (4-22): Shows The linear relation between cerebellum volume and age in group two:

Table No (4-15): Describe the Correlation of mean of Vermin area with Age class and p-value in group two:

Age class	**Mean(SD)cm^2**	**P- Value**
14 - 30 year	112.8±18.95	0.203
31 -46 year	108.6±13.93	
47 -63 year	112.2±24.61	
64 - 80 year	121.5±17.14	

** Significant at 0.01 Level

Table (4-16): Describe the Correlation of Vermin area with gender in group two:

Gender	Mean(SD)	P- Value
Female	111.1±19.73	0.281
Male	115.4±18.88	

** Significant at 0.01 Level

Chapter Five

Discussion

Chapter Five

Discussion, Conclusion & Recommendations

5.1 Discussion:

The cerebellum measurement studies are so valuable for medicine especial for neurology disorder. An awareness of normal neuroanatomical variability is important for understanding pathologic changes. In regard to the posterior fossa structures, the cumulative research record of in vivo studies is to some extents are few, and there is a need for normative data. In this prospective study, which was performed in 200 participants, were divided in to two groups equally. The first group contain 100 participants linear measurements for cerebellum and cerebrum were taken in coronal, sagittal and axial planes and were measured in (mm) using the MRI including both genders , as shown in table (4-1) which explain and describe the distribution of sample in gender which represent 39% for males and 61% for females , and was cleared in bar chart figure (4-1).

Table (4-2)describe the sample distribution of group one in six age classes with interval 9 years , the first class (14-24)years old represent 19% subject from group(1),but the second one (34-44) years old represent 14% from participants ,the third class(45-54) years old represent 23% participants , the fourth class contain (55-64) years old represent20% participants ,the fifth one contain (55-64) years old represent10% from subject ,the last class >65 which contain 14% from subjects as appear clear in figure (4-2).

This study examined two potential sources of normal variability in regional cerebellar and cerebrum measurements as seen maximum and minimum including age and gender. Table (4-3) shows the measurements of the cerebellum and cerebrum in axial and sagittal planes. The results of this study provide a valuable addition to the normative database of the cerebellar and cerebrum anatomy for Sudanese.

These data are an attempt to support the data for cerebellum norms measured in axial and sagittal images. For presentation the concept of differential aging of the cerebellum no significant age-related changes of the cerebellum were noticed, as seen in table (4-4) and figures (4-11,4-12and4-13).

Previous studies observed no age-related shrinkage of the cerebellum at the culmen noted, and there is mild decline in the area of lobules VIII through X of the cerebellum(Raz,etal 1995;Schar etal 1991), this was similar to the findings of the cerebellum measurements were mildly declined at the ages between (45-54) years old ,and (55-64)years by 3-4mm in respectively for the maximum width of cerebellum hemisphere at the axial plane .An increasing in the measurements were detected after the age of (35-44)years by 3 mm for the cerebellum height at maximum mid sagittal plane, then it was reduced at the ages between (55-64)years ,also by 3mm .The maximum value of cerebellum vermis AP width was found to be at the age between 45-54years old where an increasing by proportionally doubling in values was detected, with no significant impact of the aging and the cerebellum related measurements, this was presented in table (4-4).However this is a different approach from the observation in mostly archival samples. (Raz ,etal .1995) Such inconsistency highlights the need for accumulation of a reasonably large sample of studies, in which each study's outcome is treated as a single observation. Only a review of multiple studies gives up significant estimation of the extent of age and gender differences in cerebellar anatomy. (Hedges and Olikin, 1985).

Another study has mentioned that the topography of the cerebellum blood supply may influence the cerebellum to differential aging. The cerebellar hemispheres are supplied by the branches of the posterior inferior cerebellar artery which originates in the vertebral artery, whereas the blood supply for the age invariant superior vermis comes from the superior cerebellar artery, which branches off the basilar artery. (Lister, etal 1982; Hardy, etal .1980)

The vertebral system receives a small volume of blood in the age related vertebral insufficiency(Baloh , etal .1984) the cerebellar structures that are the most remote from the source may be at the great risk. This may be caused by changes that observed in the cerebellum readings, on the other hand one study mentioned that in contrast ,the cerebellum showed no significant age related decline in blood flow , oxygen consumption ,and glucose metabolism (Naftail ,etal. 1998; Kushner , etal .1987; Marchal ,etal 1992; Loessner , etal 1995; Moeller ,et al 1996).

Although this findings and changes are not significant but it is solely speculative, and of essential importance for more and further investigation with special attention to the evaluation of regional cerebrovascular variations within the cerebellum, as those patients may be at risk of cerebellum infarction(lister et al 1982;Hardy et al 1980).

Many studies have mentioned that the cerebellum undergo dramatic changes during childhood and adolescence. However, accurate characterization of occurring anatomical changes has been hindered by lack of longitudinal data and methodologic challenges in quantifying subdivisions of the cerebellum (Tiermer, etal.2010).

Cerebrum length at axial plane was found to be reduced significantly with aging at p =0.004 as noticed in table (4-4), and appear in figure(4-15) Several studies regarding brain, found aging associated with atrophy (Perl.T1905;Press,N,S etal 1973; Pakkenberg,H1964). Others did not find age effects until ages >55 or 60 (Marshll ,1982; Marchand , 1902; Miller , etal .1980).

The design of the study optimized comparison of young to elderly subjects ages from (14-80) years with mean age. The curve described the relationship between brain changes and age, throughout the age range to determine whether the changes is linear or it was accelerating or declining at a certain age as noticed clearly in figures[(4-15)(4-16) and (4-17)] .

This would require a larger sample in the fourth and fifth decades. However, it is noteworthy that Jernigan at(Jernigan, et al.1990) reported linear relationships with age for all measures .The additional findings concern gender differences is the comparison of length and width at axial plane . Studies have mentioned that women have lower brain volume, related to body and cranial size (Pakkenberg and Voight, 1964;Marshll,1982).

The study showed smaller measurements of cerebellum and cerebrum in females than males , where the impact of gender was affected significantly For cerebellum hemisphere maximum width at axial plane at p=0.040 and cerebrum length at axial plane at p=.005 while the other measurements were not significantly correlated with gender, this was presented in table(4-5) reverse study have mentioned that there were no sex differences in the total vermian area with significant lobule 3 sex interaction, and indicated that men had differentially larger vermian lobules and revealed no sex differences in the areas of the posterior vermis and lobules VI and VII whereas the anterior vermian area was larger in men .The volume of the cerebellar hemispheres was also greater in men although the effect of sex was not equivalent across the hemispheres for the hemisphere .The observed hemispheric volume differential between the genders was reliable. (Gurt,.etal .1991) .

One comprehensive previous study (Hedges and Olikin, 1985).

provided meaningful estimates of the magnitude of age and sex differences in cerebellar anatomy.

The finding of larger cerebellar hemispheres in men is in agreement with the literature (Raz, etal .1997) for sex differences in brain morphology, the causes and mechanisms were found to be clarified. These differences are most likely of prenatal or perinatal origin, because in contrast to sex differences in body size, sexual dimorphism of cerebral and cerebellar size is observed in children before puberty (Gieded, etal.1996) and cannot be attributed to post pubertal differences in sex hormones. This study also measured the linear cerebellum length and width in axial and coronal planes in table(4-6)in each hemispheres, which showed no obvious difference in coronal plane and symmetrical values in axial which were same in left cerebellum hemisphere ,but there were increased by(0.1±0.46mm) in right hemisphere of the cerebellum in axial plane ; as the cerebrum linear measurements for hemispheres in table (4-7),the right hemisphere just increased by (0.8±2.65mm) from the left hemisphere in axial plane , the measurements equalize in coronal plane in length and width for right and left cerebrum hemispheres and semi equal in axial plane . In the table (4-8) which explain the linear maximum measurements of cerebrum and cerebellum in axial and coronal planes which were symmetrical in all measurements expect in cerebrum length in axial and coronal which there were large difference from axial right hemisphere length which larger than coronal maximum length in the cerebrum and that may be due to some technical faults during the exam , which lead to error in measurements ; in addition to that the section which take the cerebellum and the cerebrum measuring in coronal where the lateral ventricle appears , this point showed small part from cerebrum because it was taken in more deepest section at base of skull and that was in agreements with as the previous study of . Henery C.C et al who mentioned that is greater cortical in male cerebral and cerebellum due to sexual in cortical volume dimorphism , in addition to that they said there were large size of cerebellum in length and width in male and in axial section which increase the volume automatic (Henerry , etal .1989).

Table (4-9) describe the correlation of RT cerebellum hemisphere and RT cerebrum hemisphere length and width in axial and coronal planes; table (4-10) describe the correlation of LT cerebellum hemisphere and LT cerebrum hemisphere length and width in axial and coronal planes and the correlation is strong significant with p-value 0.000**, and that explain clearly that the cerebellum hemisphere was developed with the developing of cerebrum one either RT or LT hemisphere , and that clearly appear in figures [(4-3) ,(4-4),(4-5),(4-6),(4-7), (4-8),(4-9) and (4-10)] as follow : first show the RT cerebellum hemisphere was developed in length when the RT cerebrum was developed which appear clearly in figure (4-3) which showed the RT cerebellum hemisphere length increased by 0.345mm when the RT cerebrum reach the length 131mm, but for the RT cerebellum width it was clearly presented in figure (4-5)which explain that the RT cerebellum hemisphere width increase by 0.470 mm when the RT cerebrum width reach at point 36.04mm in axial plane ,but same development of the LT cerebellum hemisphere length and LT cerebrum hemisphere length occur in axial plane as explained in figure (4-4) ,the LT cerebellum hemisphere length increase by 0.687mm when the LT cerebrum hemisphere length was developed till 109.1mm . Figure (4-6) explained the relation of the LT cerebellum hemisphere width which increase by 0.483mm when the LT cerebrum hemisphere width was developed till 35.81mm , but in coronal plane which clearly appear in figure (4-7) which explain the RT cerebellum hemisphere was developed in length when the RT cerebrum was developed which appear clearly by increasing the RT cerebellum length by 0.749mm when the RT cerebrum hemisphere length reach 106.1mm but in figure(4-8) which describe the relation of LT cerebellum hemisphere length with LT cerebrum hemisphere length in coronal plane .The LT cerebellum hemisphere length increase by .860mm when the LT cerebrum hemisphere length reach the point 111.6.

Figure (4-9) describe the RT cerebellum hemisphere width which was developed when the RT cerebrum width was developed this appear clearly when the RT cerebellum width increased by 52.98mm when the RT cerebrum hemisphere with reach 0.102mm but in figure(4-10) this describe the relation of LT cerebellum hemisphere width with LT cerebrum hemisphere width in coronal plane .The LT cerebellum width increased by 0.112mm when the LT cerebrum width reach the point 63.38mm.

The second group included 100 participants .The cerebellum volume and vermin area measurements were measured [(cm3) ,(cm2)] respectively , as presented in table (4-11) which describe the sample division for both genders included 59 females and 41 males respectively as presented in figure (4-10).

Table (4-12) explain the sample division in to age classes with interval 16 years, and the mean age was 42.36±17.87 years old (Min=14.00, Max=80.00years). The ages between (14-30) years constituting 27cases, age between (31-46) were 29subject and age between (31 -46) years old were 29 subjects and age between (47-63) years old were 28, while (64-80)years old were 16 and this variation in age sample give option to be generalization and common in whole population. And that clearly appear in figure (4-19).

Table (4-13) describe the correlation of the cerebellum volume mean with upper readings recorded in the age class of (14-30) years old with mean193.2cm^3± 24.81cm^3. The volume is decreased when the age increase the age class between (64-80) years old which emerge to plot high record or read of volume with 192.8cm^3 as the mean ± 26.88 cm^3 as noticed in figure (4-20). The results showed that the volume change with difference of age class which read 190.9cm^3 ±17.03 cm^3 in (31-46) years old and record 186.5cm3 ±19.58 cm3 in group(47-63)years old however this changes were not significantly correlated with age at P-value .672. Figure (4-22) showed that the volume declined by constant value 0.037 when the age increased starting from50.95 years old. One previous study justified that the histological finding of aging cerebellum showed general atrophy with increasing the age related to loss purkinje cells is uniformly distributed across vermin lobule and the cerebellar hemisphere (Ellis1920;Murshed etal .2003) . Another study has mentioned that the topography of the cerebellum blood supply may influence to the differential aging. The cerebellar hemispheres are supplied by the branches of the posterior inferior cerebellar artery which originates in the vertebral artery, whereas the blood supply for the age-invariant superior vermis comes from the superior cerebellar artery, which branches of the basilar artery(lister et al 1982;Hardy et al 1980).

The vertebral system receives a small volume of blood in the age related to vertebral insufficiency (Baloh, 1984), the cerebellar structures that are the most remote from the source may be at the greatest risk. This may be one of the causes of changes that observed in the cerebellum readings volume. On the other hand, one study mentioned that in contrast, the cerebellum shows no significant age related declines in blood flow, oxygen consumption, and glucose metabolism (Hayakawa, etal 1989; Raz, etal 1995) and another found no relationship between posterior fossa structures and aging (Shah , etal .1991 ;Koller,etal 1981) Others were reported a significant-associated shrinkage of the cerebellar volume in men after the age of 70 years (Ogoro etal .1998; Murshed etal 2003) .

In the previous study which was reported by (Hangmen , etal .2003)they notice that the cerebellum volume and the vermin area is decreased when the age is increasing which is agreement to the current study, and they said that the average of decreasing the cerebellum volume per year was 0.35 ml per year and they justified by decline of the white matter , which is main reason of increasing cerebellum volume in men rather than female .

On the other hand (Shah, et al.1991) reported that the dimension of the posterior cerebellar vermis does not significantly change with age. Another reported higher subjective rating of vermian atrophy by age and the trend towards atrophy is probably related to loss of Purkinje cells in the vermis and also mention in the previous study of the morphometic assessment of the brain stem and cerebellar verims which authored by murshed(Ellis , 1920 ; Murshed, etal 2003) .

Table (4-14) showed the relation between the volume and both genders which was positive propagation in males than females with mean 199.9cm^3 ±21.57 cm^3 but for female recorded mean volume of 184.1 cm^3± 19.22 cm^3 the difference between the two genders is significant at p-value.000** . This was presented in figure (4-21). Some researchers speculated that sexual dimorphism in cerebellar size can be attributed to the effects of sex hormones (Luft, etal.1997;Rhyu, etal.1999). Escalona, et al .1991. Observed that women have a significantly smaller cerebellar volume than men, but indicated no aging effect on cerebellar volume in either gender. Another study justifies the reduction of cerebellum volume in females rather than males due to reduction of white matter volume in women more than men (Ogoro ,etal .1998) .

Table (4-15) showed the veirmal area mean and the relation with age as follow, in the young ages; the vermian mean area was 112.8 cm^2 ±18.95cm^{2}in the age range (14 - 30) years old but started to decrease when the age increases. The maximum reading in adult was 121.5cm^2±17.14 cm^{2}in the ages between (64 – 80) years old . Table (4-16) showed the classification of vermis area according to gender. The area increases in males rather than females with mean 115.4cm^2 ±18.88 cm^2 .The females recorded mean value equal to 111.1 cm^2 ±19.73 cm^2, many studies have justified that issue. (Raz, etal .1998;Courchesen ,1987 ;Raz , etal.1995;Cieselsiki, et al 1994). Others were reported a significant-associated shrinkage of the cerebellar vermis in men after the age of 70 years (Oguro etal 1998 ;Haogenam,etal .2012).

Shah et al. 1991 reported that the dimension of the posterior cerebellar vermis does not significantly change associated decrease in cerebellar vermis with age. Although, the current study results showed non-significant-associated decrease in the cerebellar vermis with age. This result is in agreement with a previous studies (Escalna, et al 1991;Aylward , et al .1994) . Luft et al. 1997 suggested that women might show steeper age-related decline in the area of the vermis than do the males as mentioned by the previous study of Hoogendam ,etal(.2012)and all of them were in agreement with this study .

Table (2-4) included different population : all results agreed with the current study that ;there are increase of cerebellum volume in male rather than female as agreed with all of previous studies (Luft,etal1997;Escalona etal.1991) , in addition to that the Sudanese cerebellum volume had high values rather than other population and that may be due to ethnicity of shape of posterior fossa structure of African population ,which is more larger rather than other population , than Turkish.

5.2 Conclusion:

This study performed for cerebellum structure measurements, and the relation of measuring with gender with age for establish reference Sudanese population .

Norms of Sudanese Cerebellum and Cerebrum were established. The normal aging concern the cerebrum length, however no age related difference were noticed in the cerebellum measurements. The degree of the reduction in the cerebellar measurements is rather mild and unlikely to be significant.

Smaller measurements of cerebellum and cerebrum were noticed in females than males, where the impact of gender was affected significantly in the cerebellum hemisphere maximum width and cerebrum length while the cerebellum height and AP vermian width were not significantly correlated with gender.

Norms of Sudanese Cerebellum volume and vermian area were established. There are increasing of cerebellum volume in young ages and then the volume decreased with increasing age.

The cerebellum volume is larger in males than females. The cerebellum vermin area increase in young ages and started to shrink with increasing age then return to increase in elderly subjects.

. There are increasing of Cerebellum volume in young participants and then the volume was declined with increasing the age.

The volume of cerebellum is increasing in male rather than the female , the volume is record as 184.1 cm^3 ± 19 .22cm^3 for female and 199.9 cm^3 ±21.57cm^3 with p-value= 0.000**

The vermin area showed an increasing in the area in the age above 64 years old and record the low reading in the third and fourth age decade , the correlation with gender was increased in males with reading (115,4 cm^2 ± 18.88 cm^2) rather than female which record (111.1cm^2±19.73cm^2).

There are significant relationship between the cerebrum and cerebellum in the measurement of axial and coronal planes.

5.3 The Recommendation:

1) Future investigation for age and gender differences of cerebrum and cerebellum using larger sample size in different ethnic groups and in different areas :north, south ,east and western Sudan are needed
2) The quantitative morphometric assessment of cerebrum and cerebellum for Sudanese fetuses are importance for standardize reference

Appendix and reference

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Appendix (a -1) data collection sheet of cerebellum volume

no	Age	Sex	Cerebellum volume	Vermin measurement	Any history of hereditary or neurology disorder	History of balance disturbance	History of drink al kohl	The note

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Appendix (a -2) data collection sheet of surface measurement of cerebellum

No	Age	Sex	The cerebellum measurement														
			Axial Measurement						Coronal Measurement						Sagittal Measurement		The Note
			Max		The hemispheres				Max		The hemispheres						
			Width	Length	RT		LT		Width	Length	RT		LT		Width	height	
					Width	Length	Width	Length			Width	Length	Width	Length			

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Appendix (a -3) data collection sheet of surface measurement of cerebrum

No	Age	Sex	The cerebellum measurement														
			Axial Measurement						Coronal Measurement						Sagittal Measurement		The Note
			Max		The hemispheres				Max		The hemispheres						
			Width	Length	RT		LT		Width	Length	RT		LT		Width	height	
					Width	Length	Width	Length			Width	Length	Width	Length			

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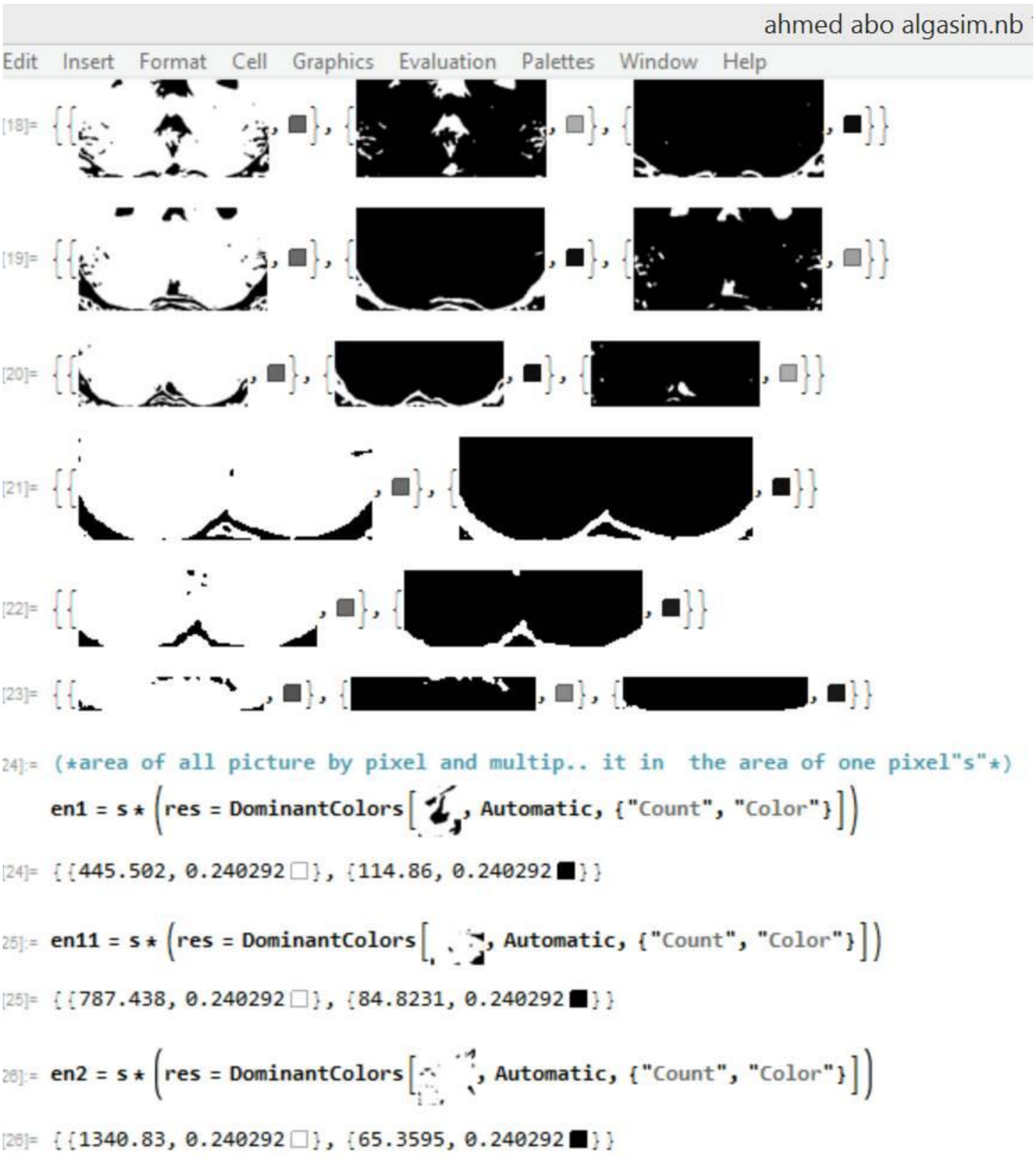
Appendix (b-1) show how wolform mathmatica programme adjust the contrast in image after applying the image adjust equation:



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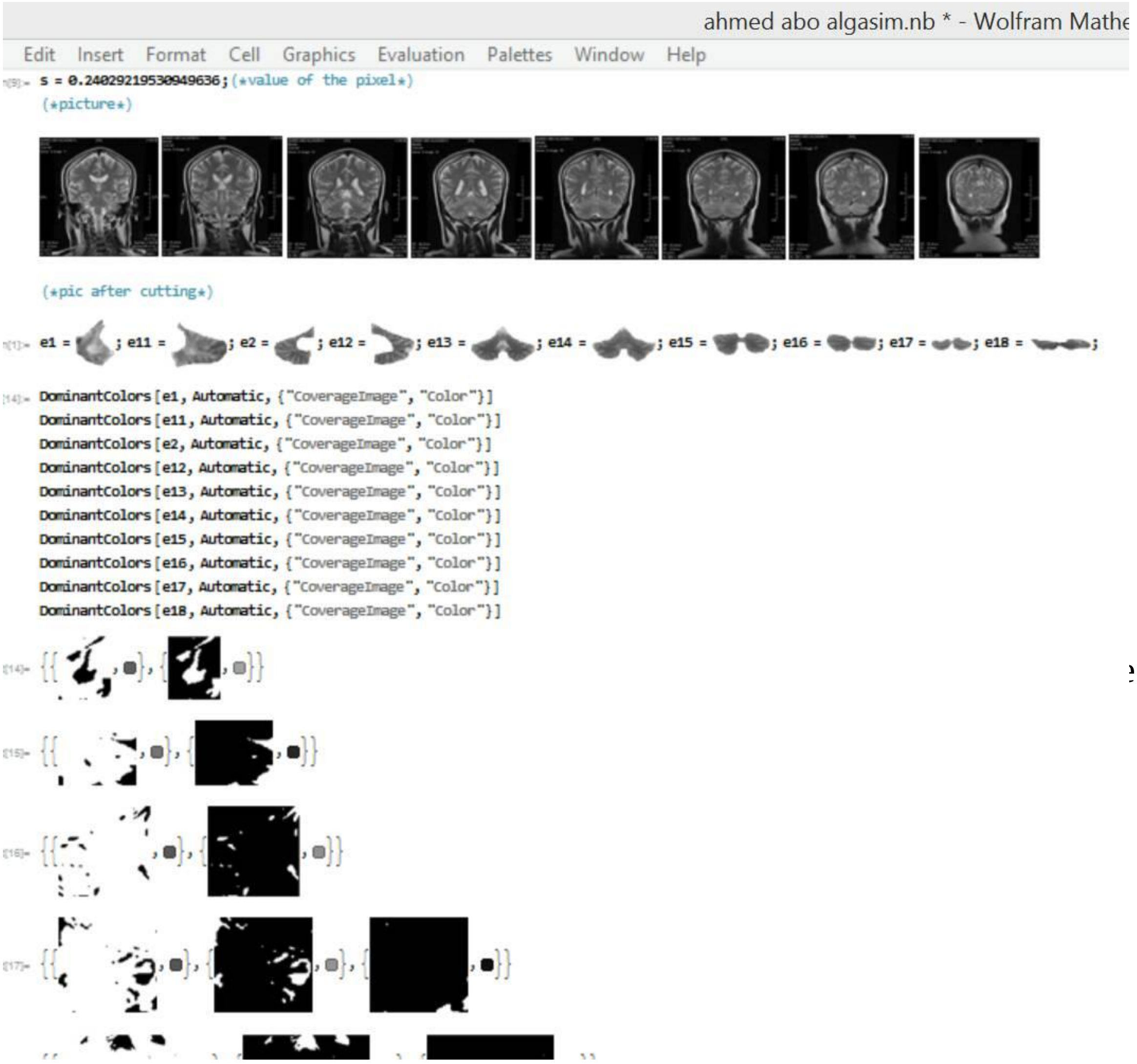
Appendix (b-2) show how the wolform Mathematica programme adjust the contrast in image by apply the image apply equation:



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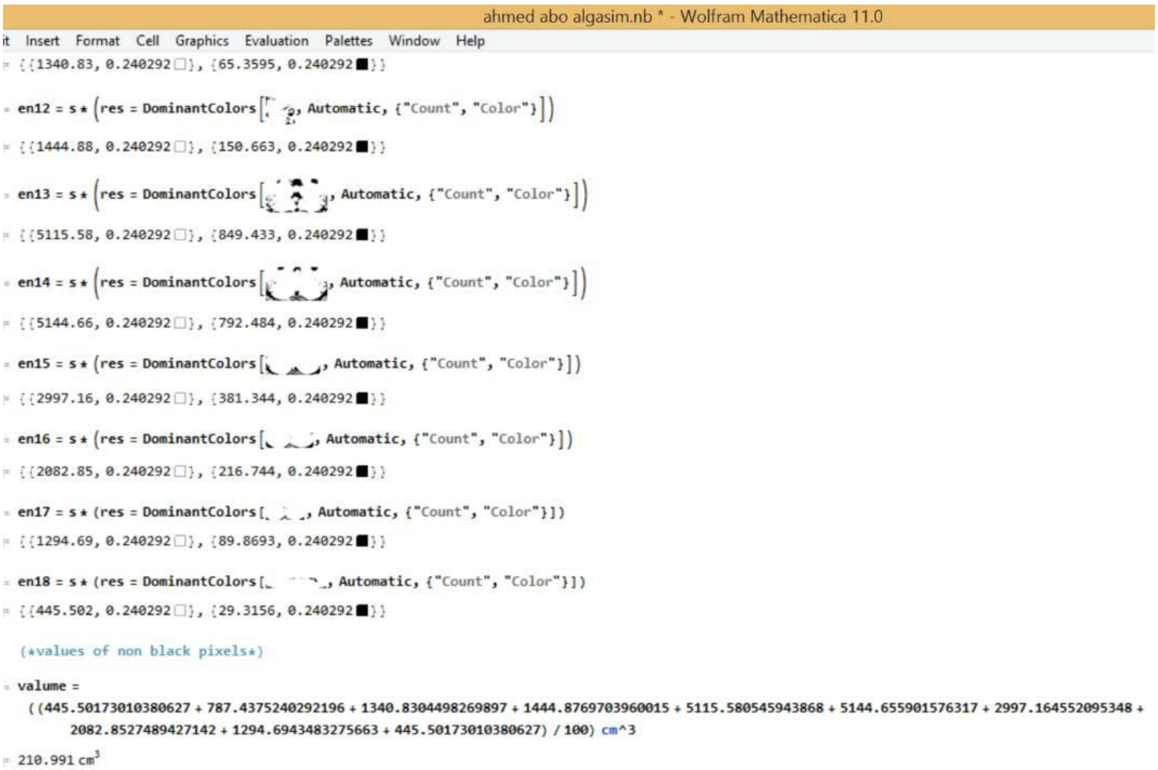
Appendix (b-3) show how programme wolform mathmatica collect and summation the slices to calculate the cerebellum volume:



ahmed abo algasim.nb * - Wolfram Mathematica 11.0

it Insert Format Cell Graphics Evaluation Palettes Window Help

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{{1340.83, 0.240292□}, {65.3595, 0.240292■}}

en12 = s * (res = DominantColors[ , Automatic, {"Count", "Color"}])
{{1444.88, 0.240292□}, {150.663, 0.240292■}}

en13 = s * (res = DominantColors[ , Automatic, {"Count", "Color"}])
{{5115.58, 0.240292□}, {849.433, 0.240292■}}

en14 = s * (res = DominantColors[ , Automatic, {"Count", "Color"}])
{{5144.66, 0.240292□}, {792.484, 0.240292■}}

en15 = s * (res = DominantColors[ , Automatic, {"Count", "Color"}])
{{2997.16, 0.240292□}, {381.344, 0.240292■}}

en16 = s * (res = DominantColors[ , Automatic, {"Count", "Color"}])
{{2082.85, 0.240292□}, {216.744, 0.240292■}}

en17 = s * (res = DominantColors[ , Automatic, {"Count", "Color"}])
{{1294.69, 0.240292□}, {89.8693, 0.240292■}}

en18 = s * (res = DominantColors[ , Automatic, {"Count", "Color"}])
{{445.502, 0.240292□}, {29.3156, 0.240292■}}

(*values of non black pixels*)

valume =
  ((445.50173010380627 + 787.4375240292196 + 1340.8304498269897 + 1444.8769703960015 + 5115.580545943868 + 5144.655901576317 + 2997.164552095348 +
      2082.8527489427142 + 1294.6943483275663 + 445.50173010380627) / 100) cm^3

210.991 cm^3
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Age And Gender Related Changes On Cerebellum Volume And Vermeil Area: MRI Based Study

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Corresponding Author: Hiba Osman Mohmmed Sied Ahmed

Abstract : *The cerebellum is one of important structure that found in posterior cranial fossa. The current study focused on the impact of age and gender on cerebellum volume and vermeil area in Sudanese population 100 healthy Sudanese subjects were included, their age ranged between14 – 80 years old,41% of them were males and 59 % were females . All were scanned using Magnetic Resonance Imaging (MRI) after applying the standard cerebellum protocol.*

The study showed : the mean cerebellum volume was 190.6 ± 21.57 $cm^3$with the maximum value was 193.2 cm^3±24.8 and was found in the ages between(14-30)years old .The minimum value was 186.5cm^3 ±19.58 and was found in the ages between (47-63)years old . There is no significant relation between cerebellum volume and age where a significant relation was found with gender and at p=0.000

The vermian minimum area was 108.6±13.93cm^2 in the ages between (31 – 46) years old and the maximum value was 121.5 cm^2 ±17.14 in the ages between (64 - 80) years old .The area is greater in males than females with no significant relation found between vermian area , age and gender.

Keywords: *Cerebellum, Vermian area, Volumetric studies, MRI*

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I. Introduction

The cerebellum is one of the important structures in the cranial fossa which occupies the posterior part. It contains more than 50% of all neurons in the brain. It is organized in manner than the cerebrum [1]Recently, researches have emphasized the role the cerebellum is likely to play in cognitive processing, next to its well-studied contributions to motor skills [2,3] It is therefore important to study determinants of cerebellar volume in a population. Most structural magnetic resonance (MR) imaging studied only the entire brain [4]. Studies that specifically assessed the cerebellum showed inconsistent results but other one reported that cerebellar volume remains relatively stable with aging [5,6] .Whereas others found strong effects regarding the impact of age on cerebellar atrophy [7,8]. A histological study of the cerebellum showed that smaller weight and volume were found, and fewer neurons were counted in the cerebellum of older persons than in those of younger persons [9].
Sex differences in gross cerebellar neuroanatomy have been reported in several studies [10-11]. Moderate shrinkage of the cerebellar hemispheres and the vermis has been noted in post-mortem studies [15, 16] and in some in vivo investigations [10-11, 12-13]. However, other volumetric studies based on MR imaging yielded no effects of age on the size of the cerebellum [14, 15] or showed non-significant trends [13]. Hayakawa et al. [16] found no significant difference in the midsagittal area of either the pons or cerebellar vermis between the 21-40 and 51-60 age groups.

The awareness of normal neuroanatomic variability is important for understanding any pathologic change . MRI studies have correlated midbrain morphology with symptomatology in several disorders, including Parkinson disease [17] and Wilson disease [18], suggesting that morphometric data may indirectly reflect underlying neurochemical or pathologic process. Coffman et al. [19] found no differences between schizophrenics and controls, whereas Nasrallah et al. [20] reported that schizophrenics have larger cerebellar structures than controls. However, a number of MRI studies could not confirm the vermal atrophy in schizophrenic patients [21-22].

The data on age-related changes of the cerebellar vermis in normal subjects will facilitate further investigation of the relation between cerebellar vermis changes and the neuromotor decline with normal aging and in different gender

Establishing normative data can be used to compare the findings in patients with neurologic disorders ,as well ,this study may support the findings of morphometrical sex differences and age-related changes as there are discrepancies in the results concerning the age-related changes in the cerebellar vermis remains speculative, though some authors suggest a selective vulnerability of specific posterior fossa structures to the effects of aging and sex.The Questions to be answered :what is the impact of age and gender on the cerebellum volume and vermial area of the Sudanese subjects

II. Materials And Methods

2.1 Area, Duration and Sample:

This is descriptive analytical study .It was performed in Khartoum state, Yastabshiroon Hospital – Radiology Department, MRI section. The study was obtained during the period extended from 2014-2017. The study was performed on 100 patients .41 were males and 59were females with different ages at range (14-80)years ,mean age was 42.36±17.87 years old(Min=14.00 , Max=80.00years). The ages between 14-30 years constituting 27 cases, ages between 31-46 were29 subjects, and ages between 47-63 years were 28, while 64-80 years old were 16, .All patients have undergone MRI brain exam complaining of headache, and their final diagnoses is normal. Any patient has problem to perform MRI brain such as patients with metallic foreign body in brain or brain clips or abnormalities at any part of cerebellum or cerebrum were excluded

2.2 MRI machine.

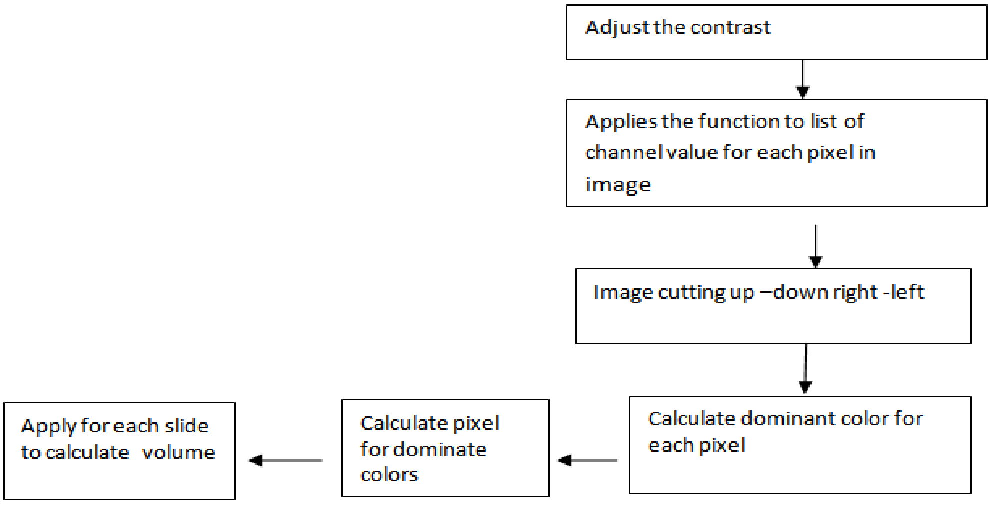
This machine is open machine and manufactured in America in 2005 and assembly in China, GE exit 0.2 Tesla .The RF Range in examination from (512-192) MHZ .The slice thickness used in MRI brain was 5mm. The matrix was 256x256.Field of view was medium.

2.3The scanning technique used and protocols:

Three planes were taken: axial (T1, T2, T1 flair), sagittal T1and coronalT2 section as routine .The measurements were done in: axial T2 FSE. Firstly: patients were prepared to enter the MRI room by removing any metallic substance outside his /her body. In the cases where anesthesia is needed, it was applied. The sequence of the exam was explained clearly for all of the patients. Secondly: the head coil was applied, then the foam pads and ear plugs to ensure the immobilization and comfortable of patients. Two control lines were applied; one is axial and the another is sagittal , the first coronal and sagittal crosses the nasion area ,the second coronal pass just at the external orbital line level , then the scan start from vertex till the base of skull.

2.4 Method of measuring the volume.

In this measurement, an advanced soft ware program (Wolfram Mathematica)[23] was used for image analysis , interpretation and application .applying the following steps:



2.5 Ethical concerns:

Verbal consent was firstly obtained from all potential participants. The aims, benefits of the present study were explained to all participants in details. Medical, history of all study subjects posing as (sample) were thoroughly reviewed directly from participants themselves and those with conditions that may in any way, alter the findings of the current study were excluded.

III. Results

Table No (1): Age class, frequency and percentage

Age Classification	Frequency	Percentage
14 -30 year	27	27%
31 - 46 year	29	29%
47 - 63 year	28	28%
64 - 80 year	16	16%
Total	100	100%

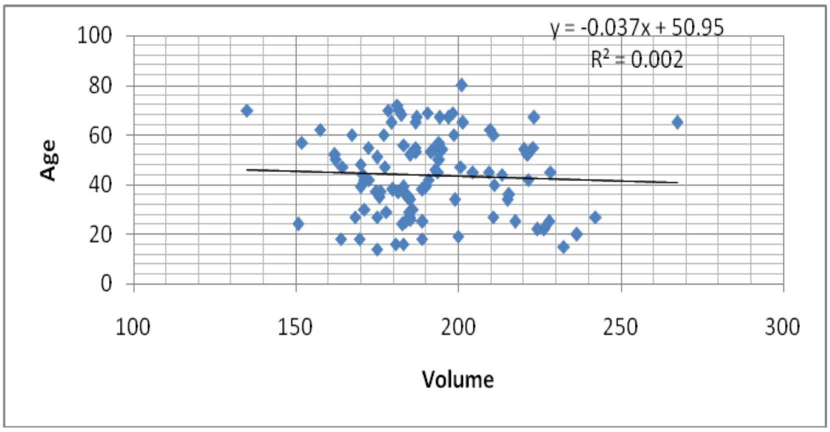
Table No (2): Gender ,Frequency and Percentage

Gender	Frequency	Percentage
Male	41	41%
Female	59	59%
Total	100	100%

Table No (3): Age class, Mean Cerebellum volume and P-value

Age Classes	Mean cerebellum volume ±STDV	P- Value
14-30 year	193.2±24.81	0.672
31 - 46 year	190.9±17.03	
47 - 63 year	186.5±19.58	
64 - 80 year	192.8±26.88	

** Significant at 0.01 Level



Figure(1): show the relation between age and cerebellum volume

Table No (4): the mean cerebellum volume for both genders and p=value

Gender	Mean(SD)	P- Value
Female	184.1±19.22	0.000**
Male	199.9±21.57	

** Significant at 0.01 Level

Table No (5): Age class, mean Vermis area and p- value

	Mean Vermis area ±STDV	P- Value
14-30 year	112.8±18.95	0.203
31 - 46 year	108.6±13.93	
47 - 63 year	112.2±24.61	
64 - 80 year	121.5±17.14	

** Significant at 0.01 Level

Table No (6): the mean Vermis area for both genders and p=value

Gender	Mean Vermis area ±STDV	P- Value
Female	111.1±19.73	0.281
Male	115.4±18.88	

** Significant at 0.01 Level

IV. Discussion

The current study highlighted the knowledge regarding the norms of Sudanese cerebellum volume and vermian area .The frequency and percentage of the age and gender were presented in **tables (1,2)**

The results showed that the volume recording high value on the age group (14-30) years old with mean193.2 cm^3±24.81 and then the volume declined with increasing age then started to increase in the age(64-80) years old however this changes were not significantly correlated with age at P-value .672

this was presented in table (3) and figure(1) that showed that the volume decline by constant value as 0.037 when the age increased starting from 50.95 years old. Previous study justified that the histological findings of the aging cerebellum shows general atrophy , as the age-related loss of Purkinje cells is uniformly distributed across the vermian lobules and the cerebellar hemispheres [24].

Another study has mentioned that the topography of the cerebellum blood supply may influence the cerebellum to differential aging. The cerebellar hemispheres are supplied by the branches of the posterior inferior cerebellar artery which originates in the vertebral artery, whereas the blood supply for the age-invariant superior vermis comes from the superior cerebellar artery, which branches of the basilar artery. [29,30]The vertebral system receives a small volume of blood in the age-related vertebral insufficiency [31], the cerebellar structures that are the most remote from the source may be at the greatest risk. This may be one of the causes of changes that observed in the cerebellum readings volume .On the other hand, one study mentioned that in contrast, the cerebellum shows no significant age related declines in blood flow, oxygen consumption, and glucose metabolism [16, 27] and another found no relationship between posterior fossa structures and aging [32,33] Others were reported a significant-associated shrinkage of the cerebellar volume in men after the age of 70 years [34]. Shah et al. [31] reported that the dimension of the posterior cerebellar vermis does not significantly change with age. Another reported higher subjective rating of vermian atrophy by age and the trend towards atrophy is probably related to loss of Purkinje cells in the vermis [24].

Table (3) showed the relation between the volume and gender which positive propagation in males than females : mean 199.9 cm^3 ± 21.57 but for female recorded mean volume equal 184.1 cm^3±19.22 the difference between the two genders is significant at p-value.000 . Some researchers speculated that sexual dimorphism in cerebellar size can be attributed to the effects of sex hormones [13, 14]. Escalona et al. [9] observed that women have a significantly smaller cerebellar volume than men, but indicated no aging effect on cerebellar volume in either gender. Another study justifies the reduction of cerebellum volume in females rather than males due to reduction of white matter volume in women more than men [34]. **Table (4)** showed the mean cerebellum volume for both genders with significant difference at p=0.000.**Table (5**) showed the veirmal area , in the young ages; the vermian mean area was 112.8 ±18.95 cm^2 in the age range(14 - 30) years old but started to decrease when the age increases . The maximum reading in adult was 121.5 cm^2 ±17.14 in the ages between (64 – 80) years old .

Table (6) showed the classification of vermis area according to gender. The area increases in males rather than females with mean 115.4 cm^2±18.88 .The females recorded mean value equal to 111.1 ±19.73, many studies have justified that issue. [25, 26, 27, 28]. Others were reported a significant-associated shrinkage of the cerebellar vermis in men after the age of 70 years [34]. Shah et al. [32] reported that the dimension of the posterior cerebellar vermis does not significantly change with age. Although, our results showed non-significant-associated decrease in the cerebellar vermis with age. This result is in agreement with a previous studies [9-22]. Luft et al. [10] suggested that women might show steeper age-related decline in the area of the vermis than do the males .

V. Conclusion

Norms of Sudanese Cerebellum volume and vermian area were established. There are increasing of cerebellum volume in young ages and then the volume decreased with increasing age. The cerebellum volume is larger in males than females. The cerebellum vermin area increase in young ages and started to shrink with increasing age then return to increase in elderly subjects.

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 Yastabshroon Hospital -Radiology Department –in which the study was obtained

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Norms for cerebellum in Sudanese –A morphometric MRI based study

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Abstract : *The cerebellum is one of the most important structures in the posterior cranial fossa. The objectives of this study were to characterize the cerebellum and cerebrum by measuring the cerebellum height , vermians AP width in the mid-sagittal plane , the maximum cerebellar hemispheric width in axial plane and the cerebrum length and width, using MRI ,as well as to determine the impact of age and gender on the measurements in healthy Sudanese adults. The data were obtained from MR multi planes images done for 100 healthy Sudanese subjects, their mean age was 42.36±17.87 years old (Min=14.00, Max=80.00 years).*
Norms for Sudanese cerebellum and cerebrum measurements were established. The cereberum length was affected by age significantly at p=0.004; however no age related differences were noticed in the cerebellum measurements. The degree of the reduction in the cerebellar measurements is mild and unlikely to be significant. Smaller measurements of cerebellum and cerebrum were noticed in females than males, where the cerebellum hemisphere maximum width and cerebrum length were affected significantly by gender, while the cerebellum height and AP vermian width were not significantly correlated with gender. The results of this study provide a valuable addition to the normative database of the cerebellar and cerebrum anatomy for Sudanese .These data are an attempt to support the norms of the cerebellum data measured in axial and saggital images. It should be taken into account in functional imaging studies of aging, when the cerebellum is considered as an appropriate structure for reference and normalization for Sudanese.
Keywords - *Cerebellum, Brain , MRI, aging, neuroanatomy .*

I. INTRODUCTION

The cerebellum is one of the most important structures in the posterior cranial fossa, it provided higher cognitive functions. Additionally, the cerebellum has a mission in behavioral and psychiatrically diseases. [1-3] Cerebellum also have a role on working memory function. [4, 5]
Cerebellum continues to improve during childhood and adolescence, suggesting that it may be undergoing significant development during this period. Few is known regarding normal development of the cerebellum during life as mentioned by Diamond et al, 2000[6].Another study raised questions about whether the developmental curves are different between females and males. [7]Studies have mentioned that, the cerebellum develops from childishness to puberty and accesses the peak levels between 10 and 13 years old for both genders.[8] It develops over a long period: it is one of the first structures in the brain to begin to differentiate, but one of the last to mature as mentioned by Susan et al. 2008. [9]
Aging of the human brain is a differential process in which significant declining in some regions coexists with relative safeguarding in others. [10-12]Although this issue is noticeable in the cerebral cortex, it is unclear whether it can be extended to the structures of the posterior fossa.
Differential aging of the cerebellar vermis lobules has also been reported. [13, 14] In one study, however, an opposite pattern was observed, that is, a significant negative age trend was found for the anterior vermis. [15, 16]
Several investigators have observed gender related differences in gross cerebellar neuroanatomy. Males were shown to have larger cerebella than those of age-matched females, although in these reports the possibility that these differences could have reflected sexual dimorphism of body size was not consistently ruled out.[14]Little is known regarding differences in the development of cerebellar compartments, despite their having important characteristics regarding function, anatomical connections with the cortex, and an important role in neurodevelopment disorders as mentioned by Ramnani et al, 2006.[17]
An awareness of normal neuroanatomic variability is important for understanding pathologic changes. In regard to the posterior fossa structures, most of the researches record of in vivo studies are few and there is a need for normative data about the cerebellum .To the best of our knowledge, no Sudanese studies were obtained and included measurements of the same individuals in the axial, and sagittals of MR images as well , in this current prospective study, we examined age and gender related differences in the height , AP vermian width in saggital

plane and the maximum transverse hemisphere width of the cerebellum in the axial plane ,as well the length and width of the cerebrum were measured in the axial plane for Sudanese Healthy individuals.

II. MATERIALS AND METHODS

This is descriptive analytical study .It was performed in Khartoum state, Yastabshiroon Hospital -Radiology Department, MRI section. The study was obtained during the period extended from 2014-2017. The study was performed on 100 patients .39 were males and 61were females with different ages at range (14-80)years ,mean age was 42.36±17.87 years old(Min=14.00 , Max=80.00years). The ages between 14-24 years constituting 19 cases, ages between 25-34 were 14 subjects, and ages between 35-44 years were 23, while 45-54 years old were 20, 55-64 were 10 and ages **>**65were14 subjects .All patients have undergone MRI brain exam complaining of headache, and their final diagnoses is normal. Any patient has problem to perform MRI brain such as patients with metallic foreign body in brain or brain clips or abnormalities at any part of cerebellum or cerebrum were excluded.

2.1 MRI machine.

This machine is open machine and manufactured in America in 2005 and assembly in China, GE exit 0.2 Tesla .The RF Range in examination from(512-192)HZ .The slice thickness used in MRI brain was 5mm routinely except in the examination for small region such as pituitary gland or optic foremen . The matrix (options) were 256x256 or 512x512 .Field of view (options) were small, medium and large.

2.2 The technique used and protocols:

Three planes were taken: axial (T_1, T_2, $T_1$with flair), sagittal $T_1$and coronalT_2 section as routine .The measurements were done in: axial T_2 FSE. Firstly: patients were prepared to enter the MRI room by taking any metallic substance outside his /her body. In the cases where anesthesia is needed, it was applied. The sequence of the exam was explained clearly for all of the patients. Secondly: the head coil was applied, then the foam pads and ear plugs to ensure the immobilization and comfortable of patients. Two control lines were applied; one is axial and the another is sagittal , the first coronal and sagittal crosses the nasion area ,the second coronal pass just at the external orbital line level , then the scan start from vertex till the base of skull.

2.3. Method of measurements:

2.3.1 Measurements done for the cerebellum at the axial plane:

First measurement was taken in axial T_2 FSE in region of interest for the cerebellum at the inner borders. The curser was at the wider point in inner border of left side of cerebellum it was pulled to another symmetrical right border, and this measurement called cerebellum width at axial image.

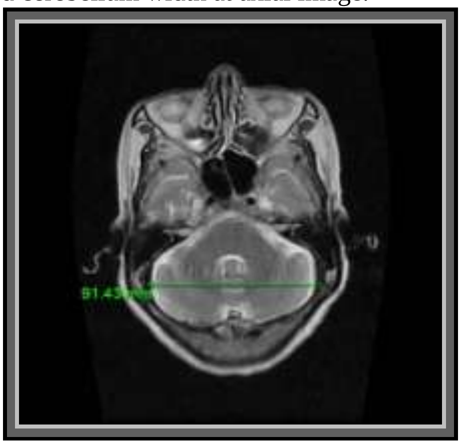


Figure (1) shows the maximum cerebellum hemisphere width in axial images

2.3.2 Sagittal cerebellum:

In this view the image was at mid saggital where the brain stem (mid brain,pons and medllua oblangata)was clear, and in this point the cerebellum height and the AP vermis width reach the maximum value ,then the curser at most upper point was positioned and was pulled till reach the lower point in another side and this measuring called cerebellum height at sagittal plane .Then the curser was moved till it reach the wider point at anterior portion and curser was pulled till it reached the posterior side and this reading called the AP cerebellum vermis width in mid sagittal plane image.

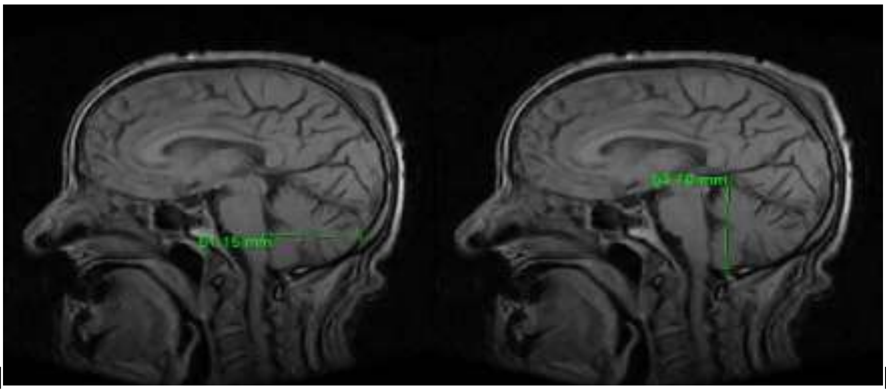
[A]  [B]

Figure (2) shows the cerebellum vermis AP width (A) and height (B)in mid sagittal images

2.3.3 Measurements done for length and width of the cerebrum at the axial plane:

The scanning was continued to upper cuts till the area of the lateral ventricles appear as shown as capital (H)in this point the measurement of cerebrum was taken ,the curser was positioned at inner border of hemispheres of the brain in mid line at the level of mid lateral ventricle ,then a line was drawn till it reach the symmetrical point at lower bottom point in image and this measure called cerebrum length at axial image .the curser was drawn till the more width point of cerebrum in the same view and was drawn from the left point from inner border till it reached the right point in the other side ,and this readings were called the cerebrum width at axial image.

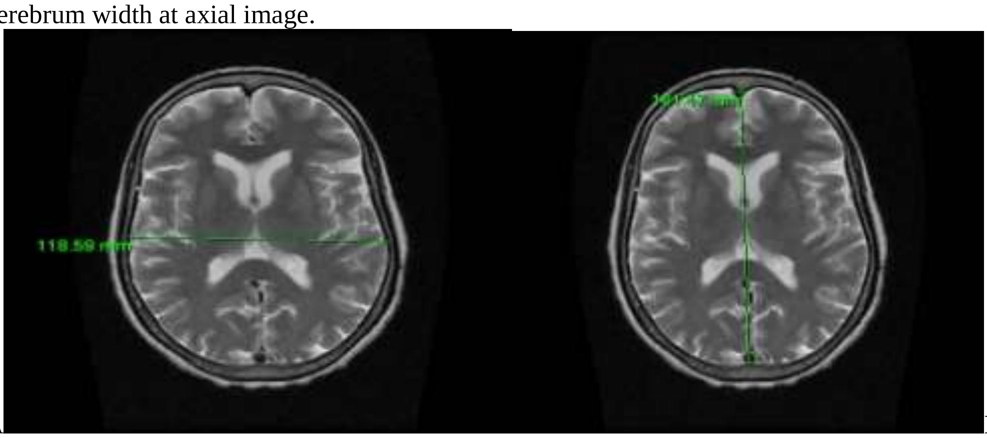
A  B

Figure (2) shows the cerebrum width (A) and Length (B)in axial images

2.4 Ethical concerns:

Verbal consent was firstly obtained from all potential participants. The aims, benefits of the present study were explained to all participants in details. Medical, history of all study subjects posing as (sample) were thoroughly reviewed directly from participants themselves and those with conditions that may in any way, alter the findings of the current study were excluded.

III. TABLES AND FIGURES

Table 1 : Descriptive statistics of cerebellum and cerebrum measured in axial and saggital planes images

Anatomical part/plane (n=100)	Min (mm)	Max (mm)	Mean (mm)	Std. V
Cerebellum hemispheric maximum width -Axial	64.29	114.76	93.54	7.70
Cerebellum height-Saggital	37.23	70.52	47.01	4.46
Cerebellum vermis AP width-Saggital	27.78	441.98	41.83	41.17
Cerebrum length -Axial	111.91	175.89	157.42	8.53
Cerebrum width -Axial	108.44	146.20	120.75	5.44

Table 2 : Descriptive statistics of the measured cerebellum hemisphere maximum width ,height , cerebellum vermis AP Width and cerebrum length and width classified according to age

Anatomical part/plane	Age Class	N	Mean (mm)	Std. v	Min (mm)	Max (mm)	P-value
Cerebellum hemisphere maximum width- Axial	14-24	19	92.29	8.43	64.29	102.45	.729
	25-34	14	94.16	5.75	84.76	108.16	
	35-44	23	95.00	6.63	79.86	106.24	
	45-54	20	92.60	6.74	71.01	108.12	
	55-64	10	91.54	12.38	67.07	104.37	
	65+	14	94.98	7.73	87.14	114.76	
	Total	100	93.54	7.70	64.29	114.76	
Cerebellum height -Sagital	14-24	19	46.40	4.07	38.69	52.62	.387
	25-34	14	46.87	3.33	41.20	51.10	
	35-44	23	46.37	4.58	37.23	61.03	
	45-54	20	49.00	6.15	42.66	70.52	
	55-64	10	46.98	3.35	40.96	50.22	
	65+	14	46.19	3.30	39.67	50.75	
	Total	100	47.01	4.46	37.23	70.52	
Cerebellum vermis AP width -Sagital	14-24	19	37.92	4.51	30.26	45.66	.386
	25-34	14	39.31	7.13	32.25	53.80	
	35-44	23	36.97	4.30	27.78	44.87	
	45-54	20	60.60	90.91	29.78	441.98	
	55-64	10	36.44	3.38	30.26	40.10	
	65+	14	34.69	4.58	27.78	45.21	
	Total	100	41.83	41.17	27.78	441.98	
Cerebrum length- Axial	14-24	19	157.57	6.88	142.33	175.89	.004
	25-34	14	165.57	4.98	157.83	173.90	
	35-44	23	155.92	6.55	142.38	171.91	
	45-54	20	156.64	8.37	139.31	167.84	
	55-64	10	155.68	16.14	111.91	167.63	
	65+	14	153.83	3.95	146.71	162.39	
	Total	100	157.41	8.53	111.91	175.89	
Cerebrum width -Axial	14-24	19	119.58	5.79	109.49	129.55	.319
	25-34	14	121.51	5.27	111.19	127.25	
	35-44	23	120.80	4.42	113.79	129.59	
	45-54	20	120.41	4.60	108.44	129.44	
	55-64	10	124.17	8.74	113.81	146.20	
	65+	14	119.51	4.61	113.96	127.64	
	Total	100	120.75	5.44	108.44	146.20	

Table 3 : Descriptive statistics of the measured cerebellum hemisphere maximum width ,height , cerebellum vermis AP Width and cerebrum length and width classified according to gender

Anatomical part/plane	Gender	N	Mean (mm)	Std. V	P-value
Cerebellum hemisphere maximum width-Axial	Male	39	95.51	8.98	.040
	Female	61	92.28	6.53	
Cerebellum height-Sagital	Male	39	46.79	4.39	.705
	Female	61	47.14	4.53	
Cerebellum vermis AP width-Sagital	Male	39	46.88	65.16	.330
	Female	61	38.61	8.98	
Cerebrum length -Axial	Male	39	160.37	7.41	.005
	Female	61	155.52	8.71	
Cerebrum width –Axial	Male	39	121.48	4.66	.283
	Female	61	120.28	5.88	

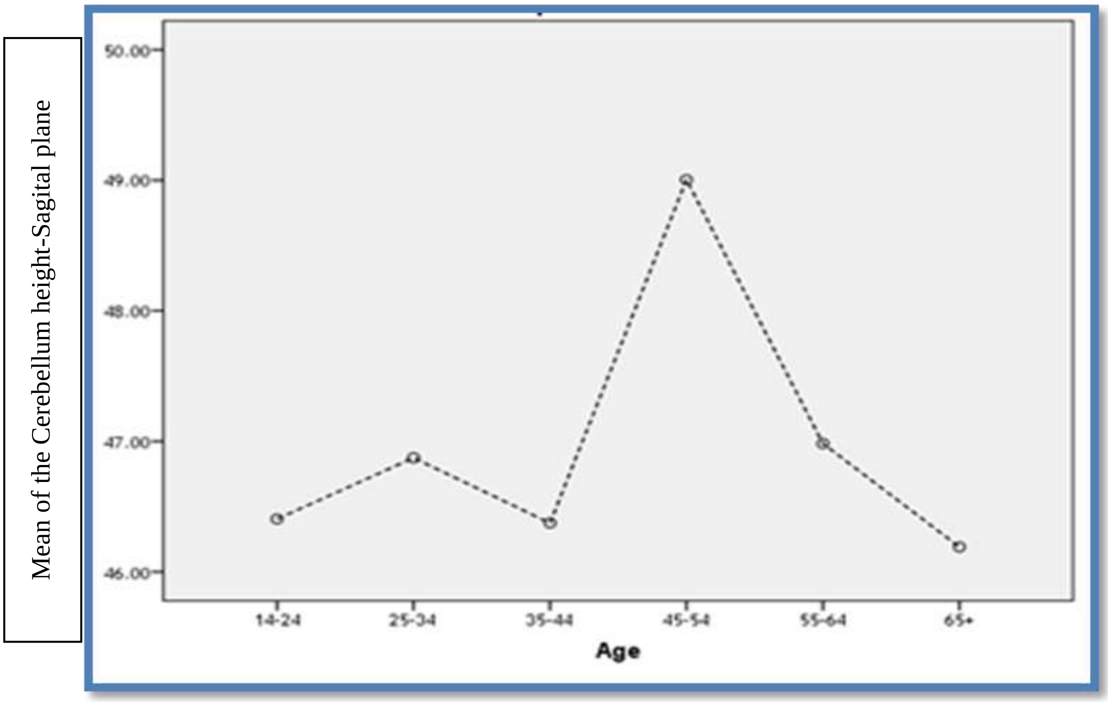


Figure 3 : The mean plot of the measured cerebellum height at saggital plane in different age groups

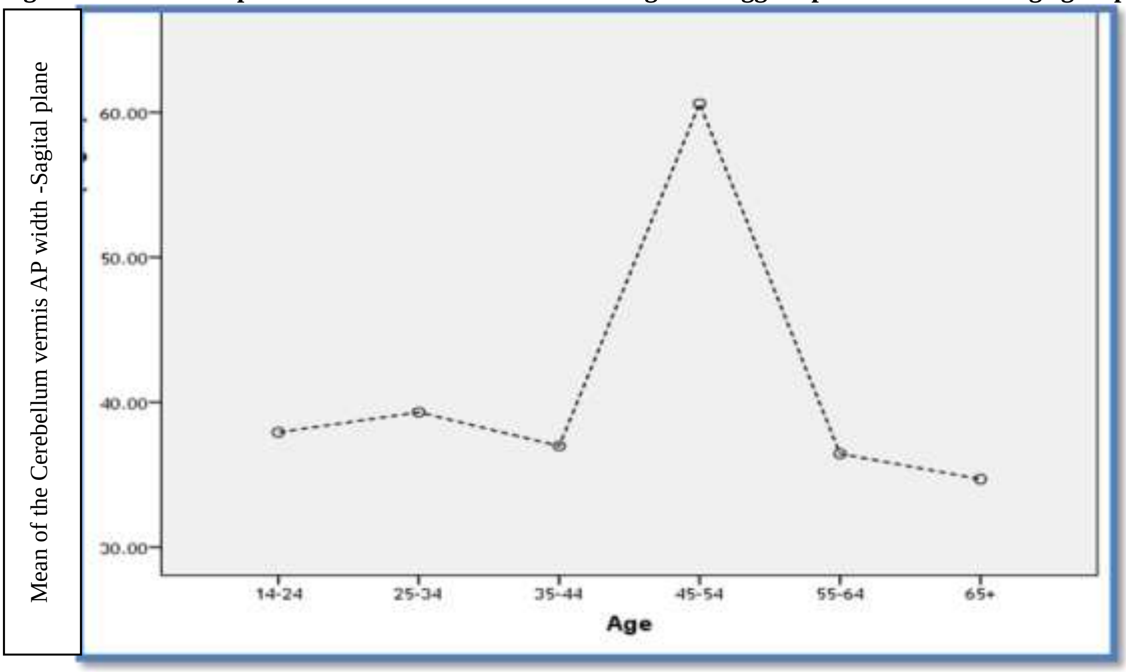


Figure 4 : The mean plot of the measured cerebellum vermis AP width at saggital plane in different age groups

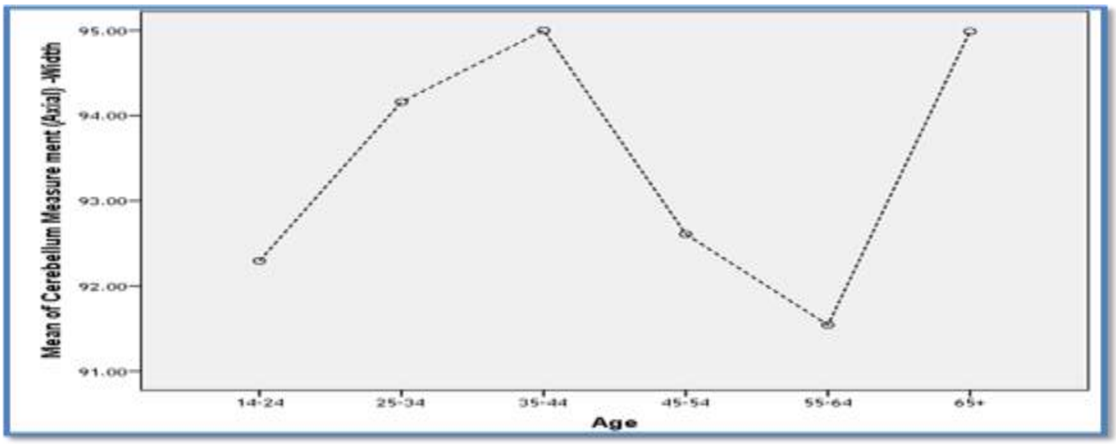


Figure 5 : The mean plot of the measured cerebellum maximum width at axial plane in different age groups

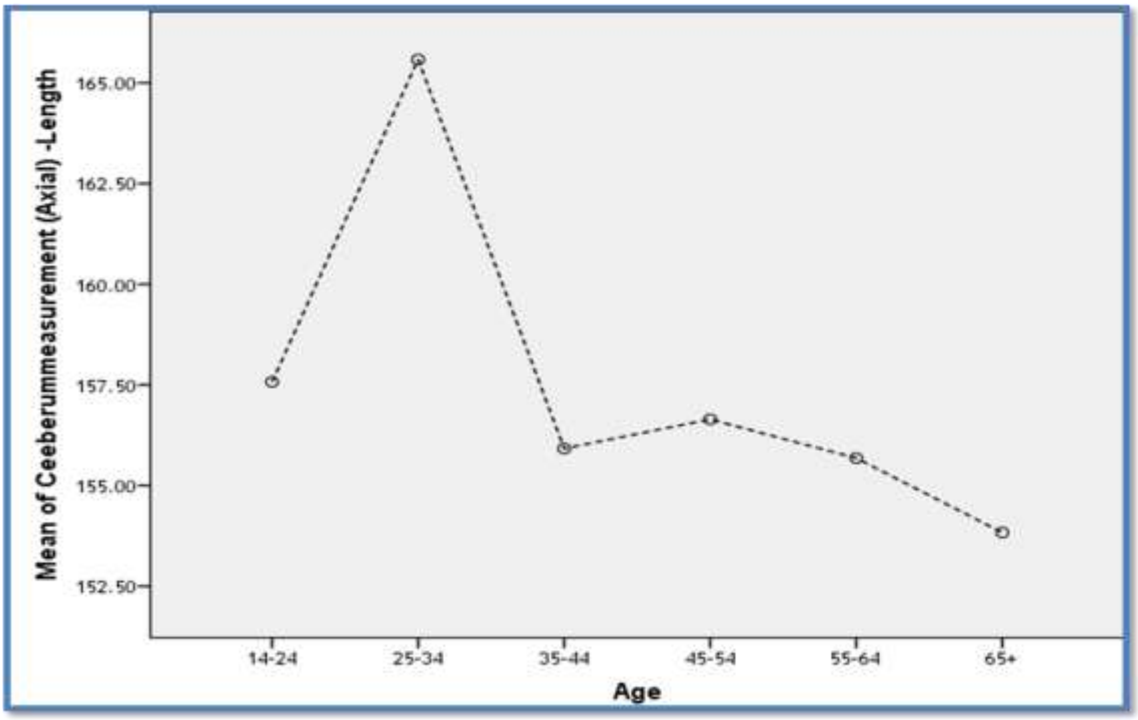


Figure 6: The mean plot of the measured cerebrum length at axial plane in different age groups

IV. DISCUSSION

An awareness of normal neuroanatomic variability is important for understanding pathologic changes. In regard to the posterior fossa structures, the cumulative research record of in vivo studies is to some extents are few, and there is a need for normative data. In our prospective study, we examined two potential sources of normal variability in regional cerebellar and cerebrum measurements as seen in figures (1and2) including: age and gender. Table (1) shows the measurements of the cerebellum and cerebrum in axial and saggital planes. The results of this study provide a valuable addition to the normative database of the cerebellar and cerebrum anatomy for Sudanese .These data are an attempt to support the data for cerebellum norms measured in axial and saggital images. For presentation the concept of differential aging of the cerebellum: no significant age-related changes of the cerebellum were noticed, as seen in table (2) and figures (3,4and5)

Previous studies observed no age-related shrinkage of the cerebellum at the culmen noted, and there is mild decline in the area of lobules VIII through X of the cerebellum[18,14], this was similar to our findings that the cerebellum measurements were mildly declined at the ages between 45-54 years old ,and 55-64 years by 3-4mm in respectively for the maximum width of cerebellum hemisphere at the axial plane .An increasing in the measurements were detected after the age of 35-44years by 3 mm for the cerebellum height at maximum mid saggital plane, then it was reduced at the ages between 55-64 years ,also by 3mm .The maximum value of cerebellum vermis AP width was found to be at the age between 45-54years old where an increasing by proportionally doubling in values was detected, with no significant impact of the aging and the cerebellum related measurements, this was presented in table (2).However this is a different approach from the observation in mostly archival samples. [14] Such inconsistency highlights the need for accumulation of a reasonably large sample of studies, in which each study's outcome is treated as a single observation. Only a review of multiple studies gives up significant estimation of the extent of age and gender differences in cerebellar anatomy. [19]

The present study results regarding the reduction or changing with age which were not significant; is in consistency to what was found in the previous study that mentioned that the mechanisms related to the observed patterns of discrepancy to aging is unclear, their study justified that the histologic findings of the aging cerebellum shows general atrophy, as the age-related loss of Purkinje cells is uniformly distributed across the vermian lobules and the cerebellar hemispheres [20]. Whatever the causes of changes of the cerebellar lobules VI and VII, they are not necessarily specific to aging, however a similar differential pattern has been observed in many diseases. [16, 21, 22, 23]

Another study has mentioned that the topography of the cerebellum blood supply may influence the cerebellum to differential aging. The cerebellar hemispheres are supplied by the branches of the posterior inferior cerebellar artery which originates in the vertebral artery, whereas the blood supply for the age-invariant superior vermis comes from the superior cerebellar artery, which branches off the basilar artery. [24,25]The vertebral system receives a small volume of blood in the age-related vertebral insufficiency [26], the cerebellar structures that are the most remote from the source may be at the greatest risk. This may be one of the causes of changes that observed in the cerebellum readings .On the other hand, one study mentioned that in contrast, the cerebellum shows no significant age related declines in blood flow, oxygen consumption, and glucose metabolism [16, 27, 28, 29, 30]

Although this findings and changes are not significant but it is solely speculative, and of essential importance for more and further investigation with special attention to the evaluation of regional cerebrovascular variations within the cerebellum, as those patients may be at risk of cerebellum infarction.

Many studies have mentioned that the cerebellum undergo dramatic changes during childhood and adolescence. However, accurate characterization of occurring anatomical changes has been hindered by lack of longitudinal data and methodologic challenges in quantifying subdivisions of the cerebellum [7]

Cerebrum length at axial plane was found to be reduced significantly with aging at p =0.004as noticed in table (2).Several studies regarding brain, found aging associated with atrophy [31,32,33]. Others did not find age effects until ages >55 or 60 [34, 35, 36]. Our results support the hypothesis of neural atrophy associated with normal aging.

The design of the study optimized comparison of young to elderly subjects (ages from 14-80 years with mean age 42.36±17.87 years. We evaluated the shape of the curve describing the relationship between brain changes and age, throughout the age range to determine whether the changes is linear or it was accelerating or declining at a certain age as noticed in figure (6)

This would require a larger sample in the fourth and fifth decade. However, it is noteworthy that Jernigan et al. [37] reported linear relationships with age for all measures .The additional findings concern gender differences is the comparison of length and width at axial planes. Studies have mentioned that women have lower brain volume, related to body and cranial size [33,34]. Our study showed smaller measurements of cerebellum and cerebrum in females than males, where the impact of gender was affected significantly for cerebellum hemisphere maximum width at axial plane at p=0.040 and cerebrum length at axial plane at p=.005while the other measurements were not significantly correlated with gender, this was presented in table (3)

One study have mentioned that a differential effect of age on certain brain components were noticed, moreover there was a gender difference.[38]

The current study showed that there is no gender difference in cerebellum, height and AP vermian width ,on the other hand ; a significant difference in cerebellum maximum width between genders were observed table(3) reverse study have mentioned that there were no sex differences in the total vermian area with significant lobule 3 sex interaction, and indicated that men had differentially larger vermian lobules and revealed no sex differences in the areas of the posterior vermis and lobules VI and VII whereas the anterior vermian area was larger in men .The volume of the cerebellar hemispheres was also greater in men although the effect of sex was not equivalent across the hemispheres for the hemisphere The observed hemispheric volume differential between the genders was reliable. [39]

One comprehensive previous study [40] provided meaningful estimates of the magnitude of age and sex differences in cerebellar anatomy.

Our finding of larger cerebellar hemispheres in men is in agreement with the literature [12], for sex differences in brain morphology, the causes and mechanisms were found to be clarified. These differences are most likely of prenatal or perinatal origin, because in contrast to sex differences in body size, sexual dimorphism of cerebral and cerebellar size is observed in children before puberty [41] and cannot be attributed to post pubertal differences in sex hormones.

V. CONCLUSIONS AND RECOMMENDATIONS

Norms of Sudanese Cerebellum and Cerebrum were established. The normal aging concern the cereberum length, however no age related difference were noticed in the cerebellum measurements. The degree of the reduction in the cerebellar measurements is rather mild and unlikely to be significant

Smaller measurements of cerebellum and cerebrum were noticed in females than males, where the impact of gender was affected significantly in the cerebellum hemisphere maximum width and cerebrum length while the cerebellum height and AP vermian width were not significantly correlated with gender.

It should be taken into account in functional imaging studies of aging, when the cerebellum is considered as an appropriate structure for reference and normalization. These findings also raise a question of the relationship between age-related declines in multiple functions of the cerebellum and deterioration of their neuro-anatomic substrates.

Future investigation of sex differences in brain morphogenesis in utero with larger sample size as well at different ethnitity, this may shed light on gross neuroanatomic differences that are observed apparently throughout the normal life span.

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