



Sudan University of Science and Technology

College of Graduate Studies

**Assessment of Radiographic Technologists Ability
in Diagnosis of Brain Magnetic Resonance
Imaging in Clinical Practice**

تقييم مقدرة تقني الأشعة على تشخيص امراض الرأس بواسطة
الرنين المغنطيسي في الممارسات السريرية

*A thesis Submitted for Partial Fulfillments for the Requirements of M.Sc.
Degree in Diagnostic Radiological Technology*

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2017

الآية

قال تعالى:

(إِنَّ الَّذِينَ آمَنُوا وَالَّذِينَ هَادُوا وَالنَّصَارَى وَالصَّابِئِينَ مَنْ آمَنَ بِاللَّهِ وَالْيَوْمِ الْآخِرِ

وَعَمِلَ صَالِحًا فَلَهُمْ أَجْرُهُمْ عِنْدَ رَبِّهِمْ وَلَا خَوْفٌ عَلَيْهِمْ وَلَا هُمْ يَحْزَنُونَ)

سورة البقرة (62)

Dedication

To my soft **Mother** the greatest person I have ever seen in my life

To my great **Father**

To my Sisters and **Brothers**

To all my **Friends**

To all **People** close my heart

Acknowledgement

My acknowledgements and gratefulness firstly to my god ,who gave us the gift of the mind and blessed and guided me to a accomplish this thesis.

My gratitude is extended to my supervisor **Prof. Mohamed Elfadil** for his support and his good guidance and help through this thesis.

My gratitude is also extended to **Mohamed Abdo** who helped me in this research and this research could never been without him.

Special thanks to **Eman Elgorshi** for her assistance in data analysis.

Finally I would like to thank ever body who helped me in preparing and finishing this study.

Abstract

MRI provides important diagnostic information that can't be obtained with other imaging techniques. MRI is particularly useful to examining the Brain, Neck and Spinal Cord. In brain MRI the high quality image that provided be it give more detailed information in the most complicated areas in the brain like mid brain and brainstem and more accurate diagnosis to abnormalities like Infarctions, Epilepsy and most types of Tumours.

The aim of this study was to determine the accuracy of radiology technologist image diagnosis in different cranial MRI cases.

A cross sectional series of 30 cases was reviewed and interpreted by 20 radiology technologists, and the results compared with the diagnosis of radiologist as reference standard opinion.

An overall accuracy of (59.9%) was achieved, with a sensitivity of (90.3%) and specificity of (65.2%). The study also found that the accuracy affected by work experience period. the most pathological diagnose was Subdural Hemorrhage and the least one which wasn't diagnosed was Epilepsy.

The results are not similar to studies of interpretation of other countries because of different style of education and job description for technologist and also hard work environment.

The study recommends that more formal educational subjects and courses in image interpretation for technologists and appropriate training program.

المستخلص

التصوير بالرنين المغناطيسي يوفر معلومات تشخيصية مهمة لا يمكن الحصول عليها من تقنيات التصوير. التصوير بالرنين المغناطيسي هو مفيد بشكل خاص في دراسة الدماغ والعنق والنخاع الشوكي. في الرنين المغناطيسي للدماغ يمكنك الحصول على صورة ذات جودة عالية تعطي معلومات أكثر تفصيلاً في مناطق الدماغ الأكثر تعقيداً مثل منتصف الدماغ وجذع الدماغ وأكثر دقة في تشخيص الأمراض مثل الجلطة، الصرع و معظم أنواع الأورام .

الهدف من هذه الدراسة هو تحديد دقة تقني الأشعة في تشخيص صور الرنين المغناطيسي في مختلف حالات التصوير بالرنين المغناطيسي للجمجمة.

جرى استعراض سلسلة مكونة من 30 حالة بأثر رجعي وتم مراجعتها وتفسيرها عن طريق 20 تقني أشعة وتم مقارنة النتائج مع تشخيص أخصائي الأشعة الطبيب كمرجع.

تم تحقيق دقة تشخيص شامة بمقدار (59.9%) مع حساسية بمقدار (90.3%) وخصوصية بمقدار (65.2%). وجدت الدراسة أيضاً أن الدقة تتأثر بالفترة الزمنية للخبرة العملية والدورات التدريبية الجانبية في تفسير الصور التي أخذت عن طريق التقني.

النتائج في هذا البحث لا توافق النتائج في الدراسات السابقة للبلاد الأخرى وذلك باختلاف منهج التعليم والوصف الوظيفي للتقني وأيضاً من بيئة العمل الصعبة. وقد كان المرض الأكثر تشخيصاً هو النزيف في الرأس والمرض الأقل تشخيصاً هو الصرع.

توصي الدراسة بزيادة المواضيع الدراسية الرسمية والدورات التي تساعد على تفسير الصور مع برامج التدريب المناسبة.

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List of Abbreviations

A&E	Accident and Emergency
AVM	Arteriovenous Malformation
CSF	Cerebral Spinal Fluid
FN	False Negative
FP	False Positive
FRCR	Fellowship of Royal College of Radiologist
Mets	Metastatic Carcinoma
MRI	Magnetic Resonance Imaging
MS	Multiple Sclerosis
SIGRR	Special Interest Group in Radiographer
TN	True Negative
TP	True Positive

Chapter one

1.1 Introduction

Radiology technologists worldwide are integral part of the diagnostic pathway and are optimally placed to provide expert comment on radiographs, by profession, the radiology technologist is the first health care professional to view each diagnostic image, which has been acquired focusing on the patient complain. Radiology technologists are in a unique position to communicate their professional observations directly with the treating clinician in a timely manner and thereby have a significant influence on patient care. Currently, advanced practitioner roles, which incorporate radiology technologist reporting, are limited to the United Kingdom (UK) only (Woznitza, 2014).

The workload of radiology departments has increased in recent years and the availability of trained radiologists is not always sufficient to meet this demand, particularly in the context of out-of-hours emergency imaging. Some departments have considered addressing this shortfall by allowing referring clinicians to report imaging studies. A major concern with employing non-radiologists to report such studies is potentially serious and consequences of an incorrect report will be the results; therefore, for this approach to be widely used it would be necessary to assess an individual's performance using a validated testing procedure. (Gallagher et al. 2011)

The changing nature of health care worldwide has been seen in several countries including Canada, Australia, Norway and Denmark develop models of advanced radiology technologist practice which includes definitive clinical reporting (Woznitza, 2014).

1.2 Problem of the study:

In Emergency Departments (ED) junior doctors regularly make critical diagnostic decisions based on MRI head images. Also, many states in Sudan needs a professional interpretation of MRI image especially in the remote areas, therefore the value of radiology technologist in image perception and reporting in Sudan haven't been assessed before, where it might help in solving the current problem.

1.3 Objectives:

1.3.1 The general objective

To assess and hence determine the accuracy of radiology technologist's perception for cranial magnetic resonance imaging in clinical practice assessment

1.3.2 Specific objectives:

- To find sensitivity, specificity and accuracy of radiology technologist in diagnosis and detection of cranial abnormality.
- To find sensitivity, specificity and accuracy of radiology technologist in diagnosis and detection of deferent abnormalities.
- To cross-correlate sensitivity, specificity and accuracy with radiology technologist experience, peripheral courses and postgraduate studies.

1.4 Overview of the study

This study consisted of five chapter with chapter one is an introduction, which include problem of the study, objective and significance of the study, while chapter two it literature review which include a brief theoretical background and previous study.

Chapter three includes material used to collect the data and the method followed to collect the data and hence.

Chapter four presented the results in table and figures and finally chapter five gives interpretation of the results, which discussed in regards to previous study as well as conclusion and recommendations.

Chapter two

Theoretical Background and Previous Studies

2.1 The development of radiographer reporting:

2.1.1 Introduction:

Larkin, in his article on occupational control, wrote that, in 1923, The Lancet defined “radiologist” as a term applied to members of the medical profession who undertake radiographic diagnosis and treatment by means of x rays and radium, whereas “radiographer” (technologist) should be applied to trained nonmedical assistants. (Larkin G,1983)

Between 1900 and 1920, there was competition between radiographers and radiologists with regard to the performance of radiography and the interpretation of radiographs. In the middle 1920s in England, radiographers were banned from accepting patients for radiography except under the direction of a qualified medical practitioner. (Larkin G,1983)

An early proposal that senior technologists who underwent a period of supplementary training could triage images to normal and abnormal categories was provided by Swinburne in 1971. (Swinburne K,1971)

2.1.2 The pressure on the radiological service:

In 1965, apparent increases in the responsibilities the radiographers were reported. There was no obvious pattern to this. Radiographer role extension was more likely to be due to the individual whims of the radiologists in those departments rather than the organized effort by radiographers. (Shanks,1965)

In 1968, the shortage of radiologists was discussed by Lodwick who explained why less than 30% of medical students thought of radiology as a career. Medical students saw radiologists as practicing physicians, almost

totally involved in clinical work, with only limited time for teaching and virtually no time for research. As a result, radiologists were understaffed, under pressure, and were being called upon to perform more specialized procedures. They had little or no time to report films. This situation had to be solved. Either radiologists were required to come up with a solution, or someone else would have, and they might not have cared for the outcome. (Lodwick GS,1968; Swinburne K, 1971; Sherwood T,1975)

These were the pressures that existed in the late 1960s and early 1970s. Radiographers were bored and frustrated with the daily routine expected from them. Radiologists were being overwhelmed by an ever-increasing workload, and there was no immediate solution to their recruitment problems. (Dellar HJ,1970)

2.1.3 Accident and emergency reporting:

In 1980, De Lacey et al. carried out a study of the impact that a radiologist's report had on the management of A&E patients. Approximately, 2% of the abnormalities reported by the radiologists, which had not been diagnosed correctly by the casualty officers, were clinically significant. Where films could not be reported immediately, it was thought to be most helpful if radiologists reviewed radiographic examinations already noted 'normal' or 'possibly abnormal'. This could reduce the number of films seen by a radiologist by up to 25%. (De Lacey G,1981)

In 1981, Mucci looked at the reporting of films from the A&E department only when this was requested. Of 1000 patients examined, 40% required a report and the radiologists picked up abnormalities that the casualty officer missed in 4% of the examinations. Of these, 2% were clinically significant, but more importantly, only half of the significantly missed 2% had been marked for a report. Where only half of the examinations were reported,

only half of the clinically significant abnormalities missed by the casualty officer were picked up. Mucci concluded that all films from the A&E department that were not to be seen by another specialist consultant, must be reported. (Mucci B,1983)

Wardrope and Chennells sought to identify whether there were any anatomical regions, which might not be reported routinely. The findings indicated that radiographs of the chest and wrist were most commonly misinterpreted by casualty officers. Reporting of films of the shoulders, hands fingers, toes and long bones seldom altered management. (Wardrope J, and Chennells PM,1985)

2.1.4 Improving accident reporting:

In 1982, Berman et al. introduced a system whereby the radiographer would signal, that an abnormality might be present, by putting a red dot on the outside of the X-ray film packet. In 1984, unknown to the casualty officers, this was extended and the radiographers had a form to complete to indicate whether an examination was considered normal, abnormal or that they were unsure. After 7 weeks, the results were reviewed. Radiographers and casualty officers missed abnormalities in approximately 4% of cases, for each group. The important point was that most of these 4% were different for each group. Just below 2% of examinations, which had been wrongly diagnosed by the casualty officers, had been correctly interpreted by the radiographers. Responsibility for the correct diagnosis and treatment of patients still rested with the casualty officers concerned. (Berman et al,1982)

In 1985, Berman et al. investigated how quickly X-ray examinations from the A&E department were reported, and were concerned that in 2% of hospitals, no routine reporting of A&E radiographs took place. Reporting was done within 48 h at 64% of the surveyed hospitals, but it took up to 1

week for 16% and 1 month for 2% of the hospitals to report films from the A&E department. It was thought that radiographers might informally assist with their film flagging system since it had already been proved that radiographers identified half the abnormalities missed by the casualty officer. Radiographer involvement in such schemes was to be encouraged. Indicating whether an abnormality was thought to be present on an X-ray film was an important and invaluable aid for the management of patients from the A&E department. (Berman et al,1985)

In 1989, Price announced that radiography degrees were going to be the basic qualification for radiographers and fracture reporting might now become part of their daily work. (Price R, 1989)

2.1.5 The Importance of a recognized course:

A comparison was made in 1991, between the radiographers' and the radiologists' assessments of A&E examinations, which showed an overall error rate, without any additional training, of around 9%. Saxton thought that specially trained radiographers could undertake reporting of A&E examinations. Radiographers were interested in this training and one hospital had already started a course. Before radiographers could report the films, they had to first obtain the agreement of the radiologists involved, and they were to be carefully selected, formally trained and tested. Additionally, the medico-legal implications had to be accepted by the hospital and radiologists were to continue doing some of this reporting and provide any necessary second opinions. (Saxton HM,1992)

In 1993, a trial study in A&E film reporting was set up at Leeds College of Health in conjunction with Yorkshire Regional Health Authority. Two radiographers were selected to participate in the trial, which included

the teaching of anatomy and physiology, pattern recognition, decision-making and audit. (Robinson PJ,1996)

They also spent some time in the A&E department and attended lectures by radiologists. The radiologist dictated the formal report while the radiographers, who were working independently, prepared a second report. Where there was disagreement, a senior radiologist prepared a third report, which became the gold standard. The radiographers produced satisfactory reports in 92% of the cases. (Robinson PJ,1996)

Loughran also reported on a 6 months training program for radiographers to report fracture radiographs and the results were encouraging. At the beginning of the trial, the radiographers were correct in 81% of their reports, and by the end of the 6-month period, this figure had risen to 95%. A limited survey of radiologists showed that the majority were in favor of selected radiographers being trained to report fracture radiographs. This delegated responsibility had to be properly organized so that the accuracy of radiographer reports could be checked and monitored. (Loughran CF,1994; Loughran CF,1996)

Callaway et al. compared the reporting abilities of radiology registrars and senior A&E radiographers who had received no special reporting training. Two groups of first year trainee radiology registrars showed a similar skill level, but the senior radiographers showed greater reporting skills than either of these first-year groups. Second year registrars outperformed the first-year registrars and did marginally better than the senior radiographers; however, the registrars with the FRCR performed the best among all. (Callaway et al,1997)

In 1995, the Department of Radiography at Canterbury Christ Church College started a 1 year course in clinical reporting, which led to a

postgraduate certificate in radiography. Students studied at home and undertook work-based tuition, with the delegated radiologists required to give each student a minimum of 30 tutorials. The students were required to attend a 1 h reporting session each week and six lectures relating to pathology and clinical management given by consultants from other departments. Block release into college took place every 6 weeks and focused on developing the competence to report and also on anatomy and physiology. In addition, the students were encouraged to participate actively in clinical meetings. This gave them the skill level and confidence to discuss radiographic images, and disagree with medical staff when their opinions differed. (Canterbury Christ Church College Department of Radiography,1995)

2.1.6 Skill-mix in radiology:

In 1996, Irving defined skill-mix as “radiographers being responsible for and training to do areas of work that had previously fallen to radiologists.” This could be achieved if the radiographer had access to the necessary training and their work was sufficiently monitored to ensure that agreed standards were being met and maintained. (Irving HC,1996)

The positive side of this for radiographers was that better use was made of their abilities. Radiologists gained by having more time to pursue interventional and other procedures and patients gained by having access to more diagnostic modalities. (Cunningham DA,1997)

Some radiologists thought that the interests of the patients were best served if radiographs were reported by a radiologist, but the radiographers disagreed. Six universities offered courses for radiographers in reporting fracture radiographs. Since some A&E examinations were seldom seen by a

radiologist, the sensible course was to train radiographers to do this. (Chapman AH,1997)

2.1.7 A Special Interest Group in Radiographer Reporting:

The ‘Special Interest Group in Radiographer Reporting’ (SIGRR) was formed in 1996, comprising both radiographers and radiologists. (Cunningham DA,1997)

The meeting discussed the standard required for a nationally recognized level of training and it was agreed that clarity was necessary so that the reader could immediately distinguish between a radiographer’s and a radiologist’s reports. Radiographers were recommended to advise the relevant medical staff to obtain a radiologist’s report if it was felt necessary. (College of Radiographers,1997)

The President of the Royal College of Radiologists said that it would not be acceptable, to them, for radiographers to report without a radiologist remaining responsible for that report. (Cunningham DA,1997)

By 1997, the College of Radiographers view was that film reporting must become a routine radiographer activity.(College of Radiographers, 1997)

2.2 Brain anatomy:

2.2.1 Meninges:

The brain is a delicate organ that is surrounded and protected by three membranes called the meninges. The outermost membrane, the dura mater (tough mother), is the strongest. This double-layered membrane is continuous with the periosteum of the cranium. Located between the two layers of dura mater are the meningeal arteries and the Dural sinuses.

The Dural sinuses provide venous drainage from the brain. Folds of dura mater help to separate the structures of the brain and provide additional cushioning and support. The Dural folds include the falx cerebri, tentorium

cerebelli, and the falx cerebelli. The falx cerebri separates the cerebral hemispheres, whereas the tentorium cerebelli, which spreads out like a tent, forms a partition between the cerebrum and cerebellum.

The falx cerebelli separates the two cerebellar hemispheres. The middle membrane, known as the arachnoid membrane (spiderlike), is a delicate, transparent membrane that is separated from the dura mater by a potential space called the subdural space. The arachnoid membrane follows the contour of the dura mater. The inner layer, or pia mater (delicate, tender mother), is a highly vascular layer that adheres closely to the contours of the brain. The subarachnoid space separates the pia mater from the arachnoid mater. This space contains cerebrospinal fluid that circulates around the brain and spinal cord and provides farther protection to the central nervous system (CNS). (Lorrie L, Connie M , 2007)

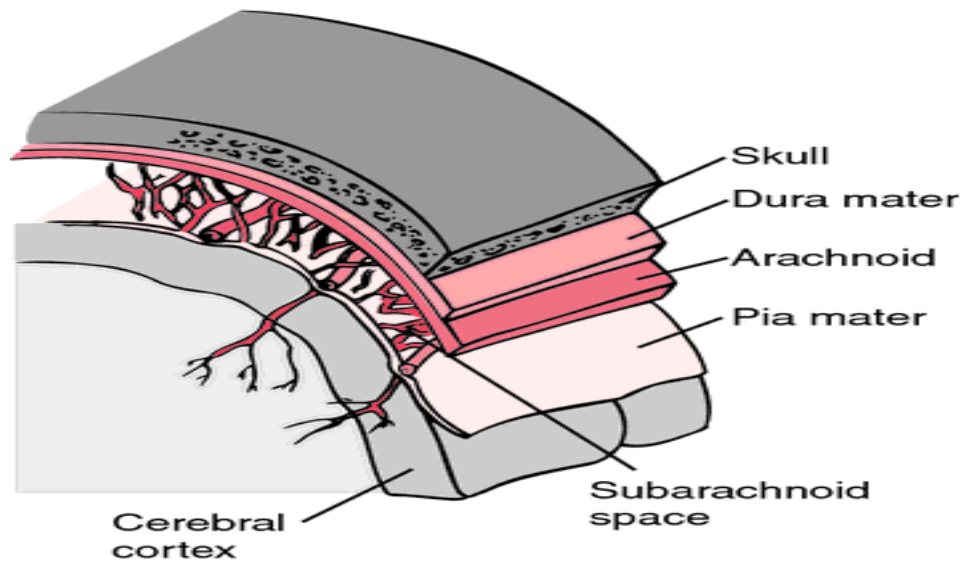


Figure (2.1): shows Meninges of the central nervous system. (The free dictionary, 2012).

2.2.2 Ventricular system:

The ventricular system provides a pathway for the circulation of the cerebral spinal fluid (CSF) throughout the CNS.

A major portion of the ventricular system is composed of four fluid-filled cavities (ventricles) located deep within the brain. The two most superior cavities are the right and left lateral ventricles.

These ventricles lie within each cerebral hemisphere and are separated at the midline by a thin partition known as the septum pellucidum. The lateral ventricles consist of a central portion called the body and three extensions: the frontal (anterior), occipital (posterior), and temporal (inferior) horns. The junction of the body and the occipital and temporal horns form the triangular area termed the trigone (atria). The lateral ventricles open downward into the third ventricle through the paired interventricular foramen (foramen of Monro). The third ventricle is a thin slitlike structure, located midline just inferior to the lateral ventricles. The anterior wall of the third ventricle is formed by a thin membrane termed the lamina terminalis, and the lateral walls are formed by the thalamus. (Lorrie L, Connie M , 2007)

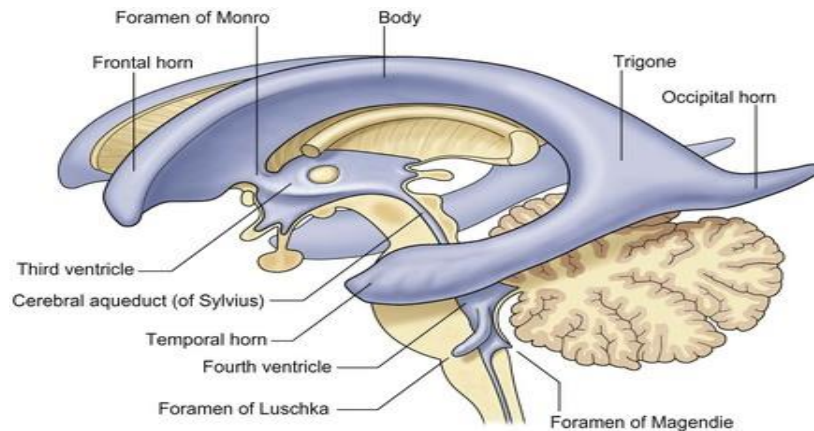
The third ventricle communicates with the fourth ventricle via a long, narrow passageway termed the cerebral aqueduct (aqueduct of Sylvius). The cerebral aqueduct reaches the fourth ventricle by traversing the posterior portion of the midbrain. (Lorrie L, Connie M , 2007)

The fourth ventricle is a diamond shaped cavity located anterior to the cerebellum and posterior to the pons. Separating the fourth ventricle from the cerebellum is a thin membrane forming the superior and inferior medullary velum.

CSF exits the ventricular system through foramina in the fourth ventricle to communicate with the basal cisterns. The major exit route for CSF passage

is the foramen of Magendie, located on the posterior wall of the fourth ventricle, which allows communication with the cisterna magna. There are two lateral apertures termed the foramen of Luschka. The apertures allow for the passage of CSF between the ventricles and the subarachnoid space.

Located within the ventricular system is a network of blood vessels termed the choroid plexus, which produces CSF the choroid plexus lines the floor of the lateral ventricles, roof of the third ventricle, and inferior medullary velum of the fourth ventricle. Frequently the choroid plexus is partially calcified, making it more noticeable on computed tomography (CT) scans. There exists a continuous circulation of CSF in and around the brain. Excess CSF is reabsorbed in the Dural sinuses by way of arachnoid villi. These villi are berrylike projections of arachnoid that penetrate the dura mater (Figure 3.2). Enlargements of the arachnoid villi are termed granulations. Within the calvaria these granulations can cause pitting or depressions that are variations of normal anatomy. (Lorrie L, Connie M , 2007)



(Figure 2.2) Components of the ventricular system. (Radiology key, 2016)

2.2.3 Cerebrum:

The cerebrum is the largest portion of the brain and is divided into left and right cerebral hemispheres. Each hemisphere contains neural tissue arranged in numerous folds called gyri.

The gyri are separated by shallow grooves called sulci and by deeper grooves called fissures. The main sulcus that can be identified on MRI and magnetic resonance (MR) images of the brain is the central sulcus, which divides the precentral gyrus of the frontal lobe and postcentral gyrus of the parietal lobe. These gyri are important to identify because the precentral gyrus is considered the motor strip of the brain and the postcentral gyrus is considered the sensory strip of the brain.

Other gyri important for imaging include the cingulate, parahippocampal, and auditory (transverse gyri of Heschl) gyri. The two main fissures of the cerebrum are the longitudinal fissure and the lateral fissure (Sylvian fissure).

The longitudinal fissure is a long, deep furrow that divides the left and right cerebral hemispheres. Located in this fissure is the falx cerebri and superior sagittal sinus. The lateral fissure is a deep furrow that separates the frontal and parietal lobes from the temporal lobe. Numerous blood vessels, primarily branches of the middle cerebral artery, follow the course of the lateral fissure. (Lorrie L, Connie M , 2007)

2.2.4 Basal ganglia:

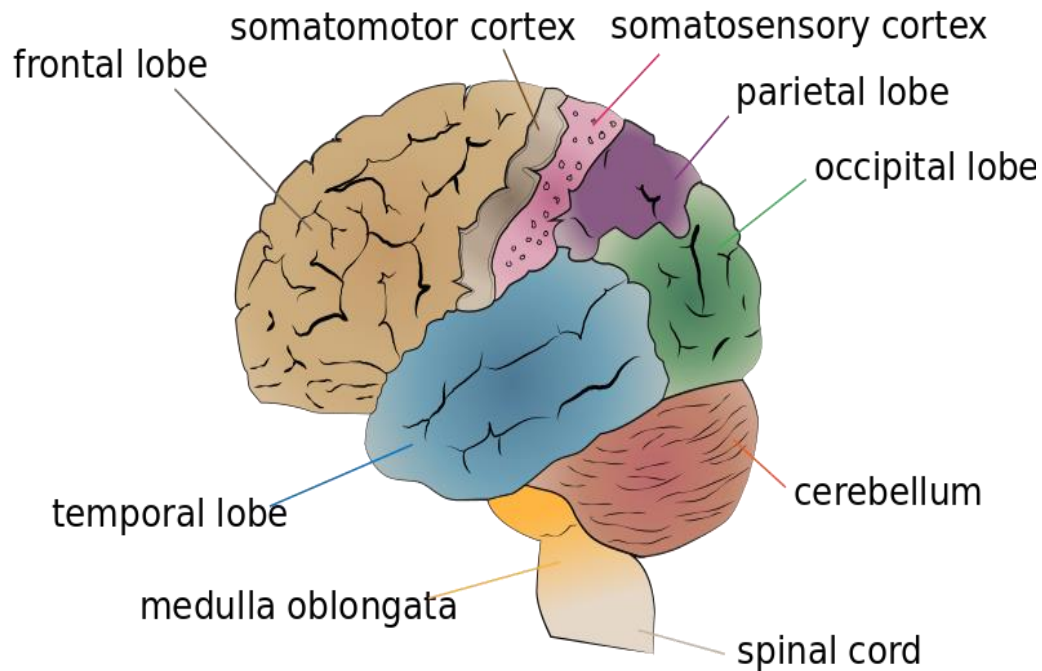
This subcortical grey matter includes the corpus striatum (the caudate and lentiform nuclei), the amygdaloid body; and the claustrum.

The Caudate nucleus is described as having a head, body and tail. Its long, thin tail ends in the amygdaloid nucleus. The caudate nucleus is highly curved and lies within the concavity of the lateral ventricle. Thus, its head projects into the floor of the anterior horn and its body lies along the body of

the lateral ventricle. Its tail lies in the roof of the inferior horn of this ventricle.

The Lentiform nucleus is shaped like a biconcave lens. It is made up of a larger lateral putamen and a smaller medial Globus pallidus. Medially, it is separated from the head of the caudate nucleus anteriorly, and from the thalamus posteriorly by the internal capsule. A thin layer of white matter on its lateral surface is called the external capsule.

The claustrum is thin sheet of grey matter lies between the putamen and the insula. It is separated medially from the putamen by the external capsule and bounded laterally by a thin sheet of white matter (the extreme capsule) just deep to the insula. The claustrum is cortical in origin but its function is unknown. (Ryan, S, et al 2011)



(Figure 2.3) Annotated lobes of the cerebrum. (Jkwchui, 2013)

2.2.5 Thalamus, hypothalamus and pineal gland:

The structures around the third ventricle include the thalamus, hypothalamus and pineal gland. Together with the habenula these form the diencephalon.

Thalamus is paired, ovoid bodies of grey matter lie in the lateral walls of the third ventricle, from the interventricular foramen anteriorly to the brainstem posteriorly. Each has its apex anteriorly and a more rounded posterior end called the pulvinar. The thalamus is related laterally to the internal capsule and, beyond that, to the lentiform nucleus. The body and tail of the caudate nucleus are in contact with the lateral margin of the thalamus. The superior part of the thalamus forms part of the floor of the lateral ventricle.

The thalamus is attached in approximately 60% of cases to the thalamus of the other side, across the third ventricle by the interthalamic adhesion or massa intermedia. This is not a neural connection.

Most thalamic nuclei are relay nuclei of the main sensory pathways. Medial and lateral swellings on the posteroinferior aspect of the thalamus are called the geniculate bodies. The medial geniculate body is attached to the inferior colliculus and is involved in the relay of auditory impulses. The lateral geniculate body is attached to the superior colliculus and is involved with visual impulses. The thalamus receives its blood supply from thalamostriate branches of the posterior cerebral artery.

Separate to and below the thalami are paired nuclei called the subthalamic nuclei which are connected to the lateral putamen and the substantia nigra. Their function is unknown but destruction of one of them causes hemiballismus.

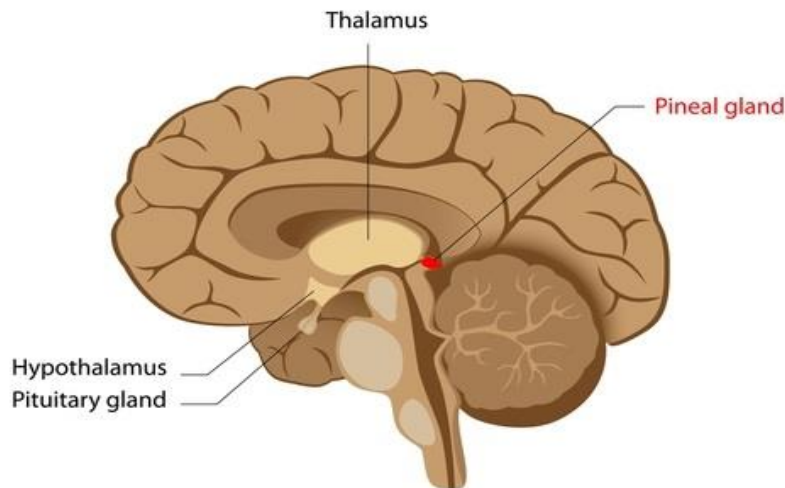
The hypothalamus forms the floor of the third ventricle. The nuclei of the hypothalamus are connected by white matter, the medial forebrain bundle, to each other, to the frontal lobe anteriorly and to the midbrain posteriorly.

The function of the hypothalamus is control of autonomic activity. It has sympathetic and parasympathetic areas and plays a role in the regulation of temperature, appetite and sleep patterns.

The hypothalamus is supplied by branches of the anterior and posterior cerebral and posterior communicating arteries and is drained by the thalamostriate veins.

The pineal gland lies between the posterior ends of the thalami and between the splenium above and the superior colliculi below. It is separated from the splenium by the cerebral veins. It lies within 3 mm of the midline.

The pineal stalk has superior and inferior laminae. The superior lamina is formed by the habenular commissure and the inferior lamina contains the posterior commissure. Between these laminae is the posterior recess of the third ventricle. (Ryan, S, et al 2011)



(Figure 2.4) The locations of the pineal gland, hypothalamus, thalamus and pituitary gland. (Alyvea, 2009)

2.2.6 Pituitary gland:

The pituitary gland (hypophysis cerebri) lies in the pituitary fossa and measures 12 mm in its transverse diameter, 8 mm in its anteroposterior diameter and 9 mm high

The pituitary gland has a hollow stalk, the infundibulum, which arises from the tuber cinereum in the floor of the third ventricle. This stalk is composed of nerve fibres whose cell bodies are in the hypothalamus. It is directed anteroinferiorly and surrounded by an upward extension of the anterior lobe, the tuberal part.

The anterior lobe is five times larger than the posterior lobe. It is developed from Rathke's pouch in the roof of the primitive mouth (A tumor from remnants of the epithelium of this pouch is called a craniopharyngioma). The anterior lobe produces hormones in response to release factors carried from the hypothalamus by hypophyseal portal veins.

The posterior lobe is made up of nerve fibers whose cell bodies lie in the hypothalamus and release hormones in response to impulses from these nerves.

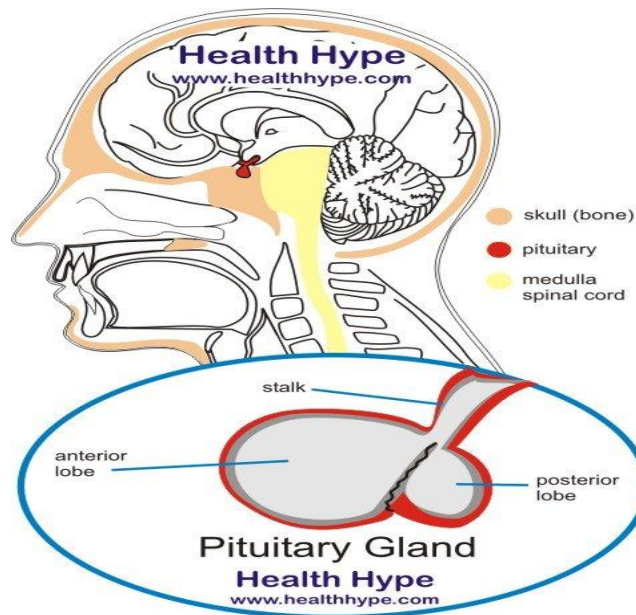
The anterior lobe is adherent to the posterior lobe by a narrow zone called the pars intermedia. This is, in fact, developmentally and functionally part of the anterior lobe.

The relations of the pituitary gland are as follows:

- Above: the diaphragma sellae (dura mater) and above this the suprasellar cistern with the optic chiasm anteriorly (8 mm above dura) and the circle of Willis.
- Below: the body of sphenoid and the sphenoid sinus.
- Laterally: the dura and the cavernous sinus and its contents, the internal carotid artery and abducens nerve with oculomotor,

ophthalmic and trochlear nerves in its walls. Inferior to the ophthalmic division of the fifth nerve is its maxillary division. More posteriorly in the lateral wall of the cavernous sinus lies the trigeminal ganglion in its CSF containing arachnoidal pouch, Meckel's cave.

The cavernous sinuses are united by intercavernous sinuses, which surround the pituitary gland anteriorly, posteriorly and inferiorly. (Ryan, S, et al 2011)

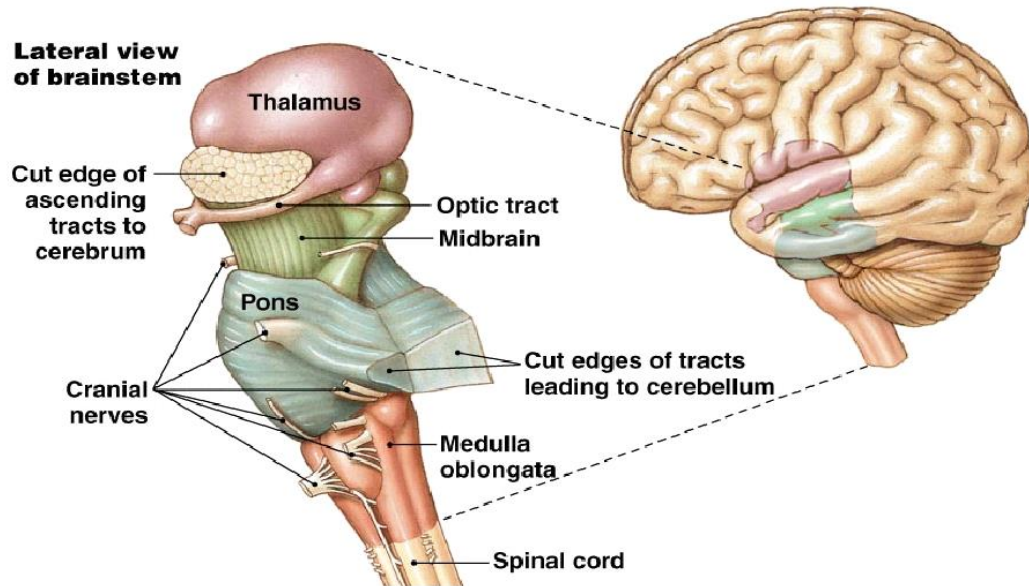


(Figure 2.5) shows Anterior and Posterior Pituitary. (Chris, 2016)

2.2.7 The brainstem:

The brainstem is a relatively small mass of tissue packed with motor and sensory nuclei, making it vital for normal brain function. Ten of the 12 cranial nerves originate from nuclei located in the brainstem. Its major segments are the midbrain, pons, and medulla oblongata. Located within the central portion of the brainstem and common to all three segments is the tegmentum, an area that provides integrative functions such as complex motor patterns, aspects of respiratory and cardiovascular activity, and regulation of consciousness.

The central core of the tegmentum contains the reticular formation, an area containing the cranial nerve nuclei and ascending and descending tracts to and from the brain. The brainstem as a whole acts as a conduit between the cerebral cortex, cerebellum, and spinal cord. (Lorrie L, Connie M , 2007)



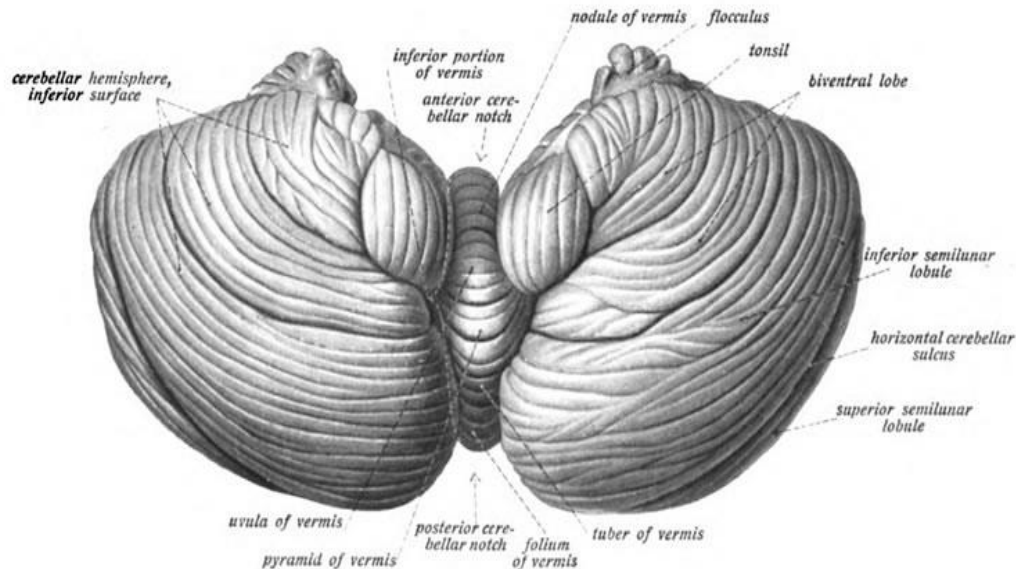
(Figure 2.6) Demonstrates Lateral view of brainstem. (cognitive consonance, 2015)

2.2.8 Cerebellum:

The cerebellum, which is referred to as the "little brain," attaches posteriorly to the brainstem and occupies the posterior cranial fossa.

The cerebellum is the coordination center for motor functions. Although the cerebellum does not initiate actual motor functions, it uses the brainstem to connect with the cerebrum to execute a variety of movements, including maintenance of muscle tone, posture, and balance, and coordination of movement. The cerebellum consists of two cerebellar hemispheres (lateral hemispheres). These hemispheres have an interesting appearance because the folds of gray matter give the appearance of cauliflower. A midline structure called the vermis connects the two cerebellar hemispheres.

On the inferior surface of the cerebellar hemispheres are two rounded prominences called the cerebellar tonsils. Occasionally, these tonsils can be seen herniating down through the foramen magnum. (Lorrie L, Connie M , 2007)



(Figure 2.7) Shows the structures of cerebellum. (Neuroscience news,2014)

2.1 Physiology of brain:

The three main components of the brain—the **cerebrum**, the **cerebellum**, and the **brainstem**—have distinct functions. The cerebrum is the largest and most developmentally advanced part of the human brain. It is responsible for several higher functions, including higher intellectual function, speech, emotion, integration of sensory stimuli of all types, initiation of the final common pathways for movement, and fine control of movement. The left hemisphere controls the majority of functions on the right side of the body; while the right hemisphere controls most of functions on the left side of the body the crossing of nerve fibers takes place in the brain stem. Thus, injury to the left cerebral hemisphere produces sensory and motor deficits on the

right side, and vice versa. One hemisphere has a slightly more developed, or dominant, area in which written and spoken language is organized. The cerebral cortex or gray matter contains the centers of cognition and personality and the coordination of complicated movements. The gray matter is also organized for different functions. The white matter is a network of fibers that enables regions of the brain to communicate with each other. Such activities as speech, evaluation of stimuli, conscious thinking, and control of skeletal muscles occur here. These activities are grouped into motor areas, sensory areas, and association areas. The cerebellum, the second largest area, is responsible for maintaining balance and finer control of movement and coordination. A stroke involving the cerebellum may result in a lack of coordination, clumsiness, shaking, or other muscular difficulties. The brain stem is the final pathway between cerebral structures and the spinal cord. It is responsible for a variety of automatic functions, such as control of respiration, heart rate, and blood pressure, wakefulness, arousal and attention. (C. Guyton and Johnson .E 2006)

2.2 Common Pathological conditions of brain:

2.2.1 Infectious diseases of brain:

2.2.1.1 Meningitis:

It is an acute inflammation of the pia mater and arachnoid. Infecting organisms can reach the meninges from a middle ear, the upper respiratory tract, or a frontal sinus infection, or they can be spread through the bloodstream. The infection may be bacterial (pyogenic) or viral in base of cased organism. Also, a chronic form of meningitis can be caused by tuberculous infection. (Eisenberg, R 2012)

2.2.1.2 Encephalitis:

a viral inflammation of the brain and meninges (meningoencephalitis), produces symptoms ranging from mild headache and fever to severe cerebral dysfunction, seizures, and coma.

A lumbar puncture (spinal tap) will show whether there is an infection in the cerebrospinal fluid. (Eisenberg, R 2012)

2.2.1.3 Brain abscess:

They are usually a result of chronic infections of the middle ear, paranasal sinuses, or mastoid air cells, or of systemic infections (pneumonia, bacterial endocarditis, osteomyelitis).

The organisms that most commonly cause brain abscesses are streptococci. In patients with acquired immunodeficiency syndrome (AIDS), unusual infections such as toxoplasmosis and cryptococcosis often cause brain abscesses. The microorganisms lodge preferentially in the gray matter and spread to the adjacent white matter. (Eisenberg, R 2012)

2.2.1.4 Subdural empyema:

It is a suppurative process in the space between the inner surface of the dura and the outer surface of the arachnoid. Approximately 25% of intracranial infections are subdural empyemas.

The most common cause of subdural empyema is the spread of infection from the frontal or ethmoid sinuses. Less frequently, subdural empyema may result from mastoiditis, middle ear infection, meningitis, penetrating wounds to the skull, craniectomy, or osteomyelitis of the skull. Subdural empyema is often bilateral and associated with a high mortality even if properly treated. (Eisenberg, R 2012)

2.2.1.5 Epidural empyema:

It is almost always associated with osteomyelitis in a cranial bone originating from an infection in the ear or paranasal sinuses. The infectious process is localized outside the dural membrane and beneath the inner table of the skull. The frontal region is most frequently affected because of its close relationship to the frontal sinuses and the ease with which the dura can be stripped from the bone. (Eisenberg, R 2012)

2.2.2 Tumors of brain:

Intracranial neoplasms manifest clinically as seizure disorders or gradual neurologic deficits (difficulty thinking, slow comprehension, weakness, headache).

About 50% of CNS tumors are primary lesions, and the others represent metastases. The clinical presentation and radiographic appearance depend on the location of the tumor and the site of the subsequent mass effect. (Sutton, D. 2003)

2.2.2.1 Gliomas:

They are the most common primary malignant brain tumors, consist of glial cells (supporting connective tissues in the CNS) that still have the ability to multiply. They spread by direct extension and can cross from one cerebral hemisphere to the other through connecting white matter tracts, such as the corpus callosum.

Gliomas have a peak incidence in middle adult life and are infrequent in persons less than 30 years of age. There are types of glial cells can produce tumors. Gliomas are classified according to the type of glial cell involved in the tumor. (Sutton, D. 2003)

2.2.2.2 Meningioma:

Meningiomas are benign tumors that arise from arachnoid lining cells and are attached to the dura.

The most common sites of meningioma are the convexity of the calvaria, the olfactory groove, the tuberculum sellae, the parasagittal region, the sylvian fissure, the cerebellopontine angle, and the spinal canal.

Of all spinal tumors, 25% are meningiomas. Seizures and neurologic defects are most often caused by mass effect. (Sutton, D. 2003)

2.2.2.3 Pituitary adenoma:

Pituitary adenomas (chromophobe adenomas), almost all of which arise in the anterior lobe, constitute more than 10% of all intracranial tumors. Most are nonsecreting Pituitary adenomas. As Pituitary tumors enlarge, the adjoining secreting cells within the sella turcica are compressed, leading to diminished secretion and decreased levels of growth hormone, gonadotropins, thyrotropic hormone, prolactin and adrenocorticotrophic hormone (ACTH).

Large Pituitary adenomas can extend upward to distort the region of the optic chiasm, whereas lateral expansion of tumor can compress the cranial nerves passing within the cavernous sinus.

A hormone-secreting pituitary tumor can cause clinical symptoms even if it is too small to have a mechanical mass effect. Hypersecretion of growth hormone results in gigantism in adolescents (before the epiphyses have closed) and acromegaly in adults (after the epiphyses have closed). Excess secretion of adrenocorticotrophic hormone results in the hypersecretion of steroid hormones from the adrenal cortex and symptoms of Cushing's disease. Hypersecretion of thyroid-stimulating hormone (TSH)

leads to hyperthyroidism. Excess secretion of prolactin by a pituitary tumor in women causes the galactorrhea-amenorrhea syndrome. (Sutton, D. 2003)

2.2.2.4 Metastatic Carcinoma:

Carcinomas usually reach the brain by hematogenous spread. Infrequently, epithelial malignancies of the nasopharynx can spread into the cranial cavity through neural foramina or by direct invasion through bone. The most common neoplasms that metastasize to the brain arise in the lung and breast. Melanomas, colon carcinomas, and testicular and kidney tumors also cause brain metastases. (Sutton, D. 2003)

2.2.3 Traumatic Processes of brain and skull:

2.2.3.1 Skull Fracture:

Linear skull fracture appears on a plain radiograph as a sharp lucent line that is often irregular or sharp and occasionally branches. The fracture must be distinguished from suture lines, which generally have serrated (saw-toothed) edges and tend to be bilateral and symmetrical, and vascular grooves, which usually have a smooth curving course and are not as sharp or distinct as a fracture line.

Depressed fractures are often star shaped, with multiple fracture lines radiating outward from a central point. The overlap of fragments makes the fracture line appear denser than the normal bone. (Kowalczyk, N 2014)

2.2.3.2 Intracranial hemorrhage:

is a collective term including many different conditions characterized by the extravascular accumulation of blood within different intracranial spaces.

A simple categorization is based on location include intra-axial hemorrhage and extra-axial hemorrhage. (Kowalczyk, N 2014)

2.2.4 Vascular disease of the brain:

The term cerebrovascular disease refers to any process that is caused by an abnormality of the blood vessels or blood supply to the brain. Pathologic processes causing cerebrovascular disease include abnormalities of the vessel wall, occlusion by thrombus or emboli, rupture of blood vessels with subsequent hemorrhage, and decreased cerebral blood flow caused by lowered blood pressure or narrowed lumen caliber.

Cerebrovascular diseases include arteriosclerosis, hypertensive hemorrhage, arteritis, aneurysms, and arteriovenous malformations (AVMs). (Kowalczyk, N 2014).

2.2.5 Multiple Sclerosis:

Multiple sclerosis is the most common demyelinating disorder; it manifests as recurrent attacks of focal neurologic deficits that primarily involve the spinal cord, optic nerves, and central white matter of the brain.

The disease has a peak incidence between 20 and 40 years of age, mostly affect women, and a clinical course characterized by multiple relapses and reductions.

Impairment of nerve conduction caused by the degeneration of myelin sheaths leads to such symptoms as double vision, nystagmus (involuntary, rapid movement of the eyeball in all directions), loss of balance and poor coordination, shaking tremor and muscular weakness, difficulty in speaking clearly, and bladder dysfunction. (Kowalczyk, N 2014)

2.2.6 Hydrocephalus:

Hydrocephalus is a condition in which there is an abnormal accumulation of cerebrospinal fluid (CSF) within the brain. This typically causes increased pressure inside the skull. Older people may have headaches, double vision,

poor balance, urinary incontinence, personality changes, or mental impairment. In babies, there may be a rapid increase in head size. Other symptoms may include vomiting, sleepiness, seizures, and downward pointing of the eyes.

Based on its underlying mechanisms, hydrocephalus can be classified into communicating and non-communicating (obstructive). Both forms can be either congenital or acquired. (Kowalczyk, N 2014).

2.5 MRI Basic principle and instrumentation

2.5.1 Basic Principle of MRI

Magnetic resonance imaging (MRI) is founded on the principle of nuclear magnetic resonance (NMR). The principles of nuclear magnetic resonance are based on the fact that the nuclei of certain elements have a magnetic moment. This means that if a sample of atoms of one of these elements were placed in a magnetic field, its nuclei would tend to line up with the field.

The nuclei don't actually line up exactly in the direction of the magnetic field, however. The laws of quantum mechanics dictate that they align at an angle to the direction of the field.

Each type of nucleus has a quality known as angular momentum associated with it. The idea of an intrinsic angular momentum of the nucleus is fundamental to magnetic resonance imaging. It can be likened to the example of a spinning top. When a top is spun at an angle to the vertical, it will precess about the vertical axis. That is, the top will rotate about its own axis, and the axis of the top's rotation will revolve about the vertical axis.

This precession is due to the angular momentum of the top, which is in turn due to the spinning of the top, in the same way; a nucleus that is aligned at

an angle to the direction of the magnetic field will precess about the axis of the field.

The analogy is so exact that the nuclei are commonly referred to as spins that are manipulated to generate images.

In quantum mechanics a number called the spin of the nucleus represents the angular momentum. Depending on the value of the spin number of a particular, there will be several different orientations in which the nuclei may line up in a magnetic field. Each orientation is represented by a different angle from the direction of the magnetic field about which the nucleus will precess.

MRI takes advantage of the fact that the nucleus of a hydrogen atom (a single proton) has a magnetic moment. The spin of the proton is such that the proton has exactly two possible ways to line up with the applied magnetic field. Because of its abundance in the body, hydrogen is a wonderful candidate for use in magnetic resonance imaging.

The frequency at which the nucleus precesses is a function of both the strength of the magnetic field and the particular nucleus. This frequency, called the Larmor frequency, and is equal to the product of the strength of the magnetic field and a constant called the gyro-magnetic ratio. The gyro-magnetic ratio is unique for each nucleus that has a magnetic moment.

The Larmor frequency is important, because it's the frequency at which the nucleus will absorb energy that will cause it to change its alignment. In proton imaging this energy is in the radio frequency (RF) range, meaning that the frequency typically varies from (1 to 100) MHz. If an RF pulse at the Larmor frequency B_0 is applied to a proton, the proton will change its alignment so that rather than being aligned with the main magnetic field, it will be aligned opposite the field. Over a period of time the proton will flip

back to align with the field. In doing so, it will emit energy whose frequency is also exactly the larmor frequency. It is this emission of energy that made NMR such a useful means to locate on image protons.

The term resonance refers to that property of the procession nucleus in which it absorbs energy only at the larmor frequency. If the frequency is off even by a small amount, the nucleus will not absorb any energy, nor will it change state. (Catherine Westbrook, 2008)

2.5.2 MRI Instrumentation:

The MRI system consists of, the magnet, the gradient coils, the radiofrequency subsystem and the computer.

2.5.2.1 The Magnet:

The heart of all MR system is the magnet. There are three types of the magnets in common use for MRI; all have in common that they can generate large uniform magnetic fields. They differ in the cost to produce the magnet, the strength that can be produced, energy requirement to support the magnet, and the direction of the main magnetic fields.

Super Conducting Magnets: By far the most commonly used magnet is the superconducting magnet. This type of magnet is notable in that the magnetic field can be maintained for a very long period of time without requiring a constant source of energy. This allows the use of this type of magnet in systems that require extremely strong magnetic field (above 0.5 T).

A superconducting magnet consists of many winding of wire that carries on electric current. The magnet field generates by this cylinder of wires runs in the direction along the long axis of the cylinder. When used to produces MR.

Images the superconducting magnet produces relatively high magnetic field strength with low power requirement.

Resistive Magnets: Resistive magnets are similar to superconducting magnets, in that they are typically coils of wire through which a magnetic field is induced. However, the wires aren't cooled to a superconductive state. Therefore, the wires are resistive, and if a current were applied and the power supply disconnected the current would eventually die out.

The major difference, therefore, is one of tradeoffs in operating cost. A resistive magnet doesn't require liquefied gases (cryogenes), but it does require a power supply to keep the magnet at a stable field. As a result of the increase in cost, these magnets aren't seen in commercial systems at field strengths over 0.4 T.

Permanent Magnets: The permanent magnet is gaining in popularity for systems that operate at magnetic fields up to about 0.4T. A large part of this popularity is due to the fact that a permanent magnet has few requirements to maintain it. While a superconducting magnet requires cryogenes, and a resistive magnet requires a power supply to maintain its current a permanent magnet requires neither.

The disadvantages of using a permanent magnet are its weight and the cost of the magnet and supporting structure. In addition, permanent magnets are susceptible to hysteresis (a time-varying change in the field). They are commonly used now for low-cost systems; the cost (and weight) of the magnets has precluded their use at higher field strengths. (Catherine Westbrook, 2008)

2.5.3 Types of Coils according to the usage:

2.5.3.1 Shim Coils:

Due to design limitation it's almost impossible to create an electromagnet, which produces a perfectly homogeneous magnetic field. To correct for these inhomogeneities, other loop of current carrying wire are placed around the bore. This process is called shimming and the extra loop of wire is called a shim coil. Shim coils produce magnetic field evenness or homogeneity. For imaging purposes, homogeneity of the order of 10 ppm is required. Spectroscopic procedures require a more homogeneous environment of 1 ppm.

The shim system requires a power supply which is separate from the other power supplies within the system. This is important because a fault in the shim power supply compromises image quality. (Catherine Westbrook, 2008)

2.5.3.2 Gradient Coils:

The magnetic field strength is proportional to the amount of current passed through the loop of wire, the number of loops in the wire, the size of the loops, and how closely the loops are spaced. If the loops are spaced closely at one end of the solenoid and gradually become farther apart at the other end, the resultant magnetic field becomes stronger at one end than the other. This is called a magnetic field gradient. Gradient coils provide a linear gradation or slope of the magnet field strength from one end of the solenoid to the other. The gradient is applied by passing current through the gradient coils in a certain direction. The amplitude of the gradient slope is determined by the magnitude of the current passing through the coil. (Catherine Westbrook, 2008)

By varying the magnetic field strength, gradient provide position dependent variation of signal frequency and are therefore used for slice selection, frequency encoding, phase encoding, rewinding and spoiling. Gradient coils are powered by gradient amplifiers. Faults in the gradient cods or gradient amplifiers can result in geometric distortion in the MR image. (Catherine Westbrook, 2008)

2.5.3.3 Radio Frequency Coils:

The energy required to produce resonance of nuclear spins is expressed as a frequency and can be calculated by the larmor equation. At field strengths used in MRI, energy within the radio frequency (RF) band of the electromagnetic spectrum is necessary to perturb or excite the spins. As shown by the larmor equation, the magnetic field strength is proportional to the RF, the energy of which is significantly lower than that of X-rays. In order to produce an image, RF must first be transmitted at the resonant frequency of hydrogen so that resonance can occur. The transverse component of magnetization created by resonance must be detected by a receiver coil. (Catherine Westbrook, 2008)

The configuration of the RF transmitter and receiver probes or coil directly affects the quality of the MR signal. There are several types of coils currently used in MR imaging. These are:

Volume Coils: A volume coil both transmit RF and receives the MR signal and is often called a transceiver. It encompasses the entire anatomy and can be used for either head or total body imaging. Because of their large size they generally produce images with lower SNR than other types of coils.

Surface Coils: Coils of this type are used to improve the SNR when imaging structures near the surface of the patient (Such as lumbar spine). As

the SNR is enhanced when using local coils (surface coils) greater spatial resolution of small structures can often be achieved when using local coils, the body coil is used to transmit RF and the local coil is used to receive the MR signal.

Phase Array Coils: Phased array coils are now widely used. These consist of multiple coils and receivers whose individual signals are combined to create one image with improved SNR and increased coverage. Therefore the advantages of small surface coil (increased SNR and resolution); can be combined with a large FOV for increased anatomy coverage. Usually up to four coils and receiver are grouped together to increase either longitudinal coverage (for spin imaging), or to improve uniformity across a whole volume (pelvic imaging).

Circumferential Coils: At the point where depth equals radius of the structure being imaged, the coil may be placed around the object in a circumferential fashion to form a solenoid. Circumferential coils provide good signal responses across the image because all points are within one radius from the edge of the coil. Two general configurations are possible with circumferential coils: solenoidal and saddle. It can be used to image the neck, knee, ankle and pediatric. (Catherine Westbrook, 2008)

2.5.3.4 The computer system

MRI computer systems vary with manufacture. Most however consist of:
Aminic computer with expansion capabilities, An array processor for Fourier transformation

An image processor that takes data from the array processor to form an image

Hard disc drives for storage of raw data and pulse sequence parameters.

A power distribution mechanism to distribute and filter the alternating current. (Catherine Westbrook, 2008)

2.5.4 Spin Echo Pulse Sequences:

2.5.4.1 Conventional spin echo:

The spin echo sequence utilizes a 90° excitation pulse to flip the net magnetization vector (NMV) into the Transverse plane. The NMV precesses in the transverse plane, inducing a voltage in the receiver coil. The precession paths of the magnetic moment of the nuclei within the NMV are translated into the transverse plane. When the 90° RF pulse is removed a free induction decay signal (FID) is produced. T2 dephasing occurs immediately and the signal decays. A 180° RF pulse is then used to compensate for this dephasing.

Spin echo pulse sequences are the gold standard for most imaging. They may be used for almost every examination. T1 weighted images are useful for demonstrating anatomy because they have a high signal to noise ratio (SNR). In conjunction with contrast enhancement however, they can show pathology. T2 weighted also demonstrate pathology. Tissues that are diseased are generally more edematous and/or vascular. They have increased water content and consequently, have high on T2 weighted image and can therefore be easily identified. The conventional spin echo has the advantages of good image quality, very versatile and true T2 weighted sensitive to pathology. They have the disadvantages of requiring longer scan time. (Catherine Westbrook, 2008)

2.5.4.2 Fast Spin Echo (Turbo Spin Echo):

As the name suggests, fast spin echo (FSE) is a spin echo pulse sequence, but with scan times that are drastically shorter than conventional spin echo.

As the scan time is a function of the TR, NEX and number of phase encoding, in order to reduce the scan time, one or more of these factors should be reduced. Decreasing the TR and the NEX affects image weighting and SNR which is undesirable. Reducing the number of phase encodings reduces the spatial resolution, which is also a disadvantage. In fast spin echo, performing more than one phase encoding step and subsequently filling more than one line of K space per IR reduce the scan time. This is achieved by using an echo train that consists of several 180°-rephrasing pulses, at each rephrasing an echo is produced and a different phase encoding step is performed.

In conventional spin echo, raw image from each echo stored in K space, and the numbers of 180° rephrasing pulses applied corresponds to the number of echoes produced per TR. Each echo is used to produce a separate image. In fast spin echo, data from each echo is placed into one image. The number of 180° rephrasing pulses performed per TR corresponds to the number is called the turbo factor or the echo train length. As the turbo factor increase, the scan time decrease, as more phases encoding steps are performed per TR. (Catherine Westbrook, 2008)

The advantages of the fast spin echo is that, the scan times greatly reduced, high-resolution matrices and multiple NEX can be used, and image quality improved, and increased T2 information.

The disadvantages are some flow and motion affects increased, incompatible with some imaging options, fat bright on T2 weighted images, image

blurring can result as data is collected at different TE times, reduce magnetic susceptibility effect as multiple 180° pulses produce excellent rephrasing so it should not be used when hemorrhage is suspected

In recent years, fast spin echo (FSE) sequences have begun to replace conventional spin echo sequences. (Catherine Westbrook, 2008)

2.5.4.3 The Gradient Echo Pulse Sequence:

A gradient echo pulse sequences utilizes an RF excitation pulses that is variable, and therefore flips the NMV through any angle (not just 90°). A transverse component of magnetization is created, the magnitude of which is less than in spin echo, where all the longitudinal magnetization is converted to the transverse plane. When a flip angle other than 90° is used only part of the longitudinal magnetization is converted to transverse magnetization, which precesses in the transverse plane and induces a signal in the receiver coil.

Gradient echo pulse sequences can be acquired $T2^*$, $T1$ and proton density weighted, however, there is always some degree of $T2^*$ weighted present on any image due to the absence of 180° rephrasing pulse. Gradient echo sequence allow for reduction in the scan time as the TR is greatly reduced. They can be used for signal slice breath-hold acquisition in the abdomen, and for dynamic contrast enhancement. They are very sensitive to flow as gradient rephrasing is not slice selective, so flowing nuclei always give a signal, as long as they have been previously excited. Because of this, gradient echo sequences may be used to produce angiography, type images. They provide interesting capabilities in term of contrast and speed. These techniques can be broadly divided into " steady state " sequences, such as gradient recalled steady state (GRASS) and fast imaging with steady state

free precession (FISP), and " spoiled " sequences, such as fast low-angle signal-shot (FLASH) and (spoiled GRASS). (Catherine Westbrook, 2008)

2.5.4.4 Three-Dimensional Fourier Transform (3DFT):

The great attraction of this technique is that a high resolution volume data set can be processed retrospectively to generate any arbitrarily oriented plane of section. For instance, a radial image can be produced using suitable software. Three-dimensional acquisition is only practical with fast scan sequences.

The advantages of 3DFT imaging are the ability to acquire thin section without gaps and the potential for 3D rendering and reformatting. The disadvantages of 3DFT imaging is that the costs include a significantly larger requirement for resources such as computing power, memory, display, and storage. Other less well-established concerns are that the examinations may take longer to interpret, given that more sections must be viewed, and that there may be a penalty in signal-to-noise and contrast, which accompanies the requirement. (Catherine Westbrook, 2008)

2.5.4.5 Inversion Recovery:

Inversion recovery is a pulse sequences that begins with a 180° inverting pulse. This inverts the net magnetization vector (NMV) through 180° into full saturation. When the inverting pulse is removed the NMV begins to relax back to B_0 .

A 90° excitation pulse is then applied at a time from the 180° inverting pulse know as time from inversion (I 1). The contrast of the resultant image depends primarily on the length of the TI. If the 90° excitation pulse is applied after the NMV has relax back through the transverse plane the contrast in the image depend on, the amount of longitudinal recovery of each

vector (as in spin echo). The resultant image is heavily T₁ weighted, as the 180° inverting pulse achieves full saturation and ensure a large contrast difference between fat and water.

If the 90° excitation pulse is not applied until the NMV has reached full recovery, a proton density image result, as both fat and water have full relaxed.

After the 90° excitation pulse, a 180° rephasing pulse is applied at a time TB after excitation pulse. This produces a spin echo. The TR is the time between each 180° inverting pulse.

Inversion recovery is used to produce heavily T₁ weighted images to demonstrate anatomy. The 180° inverting pulse produce a large contrast difference between fat and water because full saturation of the fat and water vectors is achieved at the beginning of each repetition. Inversion recovery pulse sequences therefore produce more heavy T₁ weighting than conventional spin echo and should be used when this is required. As the use of contrast primary shortens T₁ times of certain tissue, IR pulse sequences increase the signal from structures that have enhanced as a result of a contrast injection.

Inversion recovery has the advantages that it gives very good SNR, as the TR is long and excellent T₁ contrast. The disadvantage that is it spends along scan times unless used in conjunction with fast spin echo. (Catherine Westbrook, 2008)

2.5.4.6 STIR (short T₁ inversion recovery):

Is an inversion recovery pulse sequence that uses a T₁ that corresponds to the time it takes fat to recover from full inversion to the transverse plane so that there is no longitudinal magnetization corresponding to fat, When the

90° excitation pulse is applied, the fat vector is flipped through 90° to 180° and into full saturation, so that the signal from fat is nulled. STIR is used to achieve suppression of the fat signal in a T1 weighted image.

One of the advantages of STIR is that it is relatively reliable and system independent. As in spin echo, the contrast mechanism can be fairly easily reproduced from system to system and field strength to field strength, with appropriate correction of timing parameters.

The primary disadvantages lies with scan time. STIR scan time, as for inversion recovery sequences, can be computed as the product {TR x NEXx Matrix}. Since relatively long TR values are generally used, this resultant in scans times comparable to even longer than standard T2 weighted spin echo sequences.

In addition, we must be careful in the use contrast agent in conjunction with STIR sequences. Gadolinium will shorten the T1 relaxation rate for vascularity, its T1 value will not be affected, and however, fatty lesions may experience some T1 shortening and therefore have reduced effectiveness in fat suppression. The combination of STIR with gadolinium enhancement has proven useful in the evaluation of breast lesion where sufficiently suppression of the fat signal combined with enhancement of the lesion has been shown to increase delectability. (Catherine Westbrook, 2008)

2.5.4.7 Spectral pre-saturation Inversion Recovery (SPIR):

This method is a combination of the spectral saturation and (STIR) routines it is available on Philips scanners where it is designated Spectral Inversion Recovery (SPIR and GE scanners with the designation Spectral Inversion at Lipids (SPECIAL). The idea is to apply a spectrally selective pulse to flip fat spins then, after the time interval that lets the Mz of fat reach zero, the

excitation pulse is applied and the signal of the water spins give most of the signal.

Time is the major disadvantage of this fat suppression method. The routine is best applied at least once per TR, and for multi-slice sequences once per slice per TR. The best fat suppression is achieved with a 180 degree spectral inversion pulse and a time delay equal that used in normal STIR imaging (approximately 150 msec at 1.5 T) plus the finite time required for the inversion pulse) This is clearly impractical for anything but extremely long TR techniques.

In practice the "inversion" pulse used ranges between slightly more than 90 degrees but significantly less than 180 degrees the required delay time can be acceptably short. In most scanners using this method the radiographer has control of the inversion flip angle and the system determines the optimum delay time The routine is applied in a "segmented" fashion allowing some small variation in the degree of fat suppression across slices.

SP1R will be as sensitive to local field inhomogeneity as spectral saturation routines. It is suitable for use after Gd contrast because only the fat spins are affected by the routine. (Catherine Westbrook, 2008)

2.6 Previous studies:

In study done by KeithPiper^aNigelThomas (2009) under title of: **MRI reporting by radiographers: Findings of an accredited postgraduate programme**

To analyse the objective structured examination (OSE) results of the first three cohorts of radiographers ($n = 39$) who completed an accredited postgraduate certificate (PgC) programme in reporting of general magnetic resonance imaging (MRI) investigations and to compare the agreement rates with those demonstrated for a small group of consultant radiologists.

Forty MRI investigations were used in the OSE which included the following anatomical areas and abnormal appearances: knee; meniscal/ligament injuries, bone bruises, effusions and osteochondral defects; lumbar spine: intervertebral disc morphology, vertebral collapse, tumours (bone and soft tissue), spinal stenosis and/or nerve root involvement; internal auditory meati (IAM): acoustic neuroma. Incidental findings included maxillary polyp, arachnoid cyst, renal cyst, hydroureter, pleural effusion and metastases (adrenal, lung, perirenal and/or thoracic spine). Sensitivity, specificity and total percentage agreement rates were calculated for all radiographers ($n = 39$) using all reports ($n = 1560$). A small representative subgroup of reports ($n = 27$) was compared to the three consultant radiologists' reports which were produced when constructing the OSE. Kappa values were estimated to measure agreement in four groups: consultant radiologists only; radiographers and each of the consultant radiologists independently.

The sensitivity, specificity and agreement rates for the three cohorts (combined) of radiographers were 99.0%, 99.0% and 89.2%, respectively. For the majority (5/9) of anatomical areas and/or pathological categories no significant differences ($p < 0.05$) were found between the mean Kappa scores ($K = 0.47-0.76$) for different groups of observers, whether radiographers were included in the group analysis or not. Where differences were apparent, this was in cases (4/9) where the variation was either not greater than found between radiologists and/or of no clinical significance. These results suggest therefore that in an academic setting, these groups of radiographers have the ability to correctly identify normal investigations and are able to provide a report on the abnormal appearances to a high standard. Further work is required to confirm the clinical application of these findings.

In study done by K.J.PiperK.L.Buscall (2007) under title of: **MRI reporting by radiographers: The construction of an objective structured examination**

The aim was to construct a bank of general magnetic resonance imaging (MRI) investigations where good agreement was demonstrated between three independent radiological reports. The bank was subsequently to be used to assess radiographers' ability to accurately report at the end of an accredited programme; Postgraduate Certificate (PgC) Clinical Reporting (MRI—General Investigations).

Eighty-seven examinations (33 knee, 36 lumbar spine and 18 internal auditory meatus—IAM) were initially reported by two radiologists. Seventy-two of these examinations (25 knee, 29 lumbar spine and 18 IAM) were subsequently reported by a third radiologist. Interobserver agreement was

assessed by estimating the total, positive and negative % agreement rates; and by use of the weighted or unweighted kappa values. Knee reports were analysed for meniscal tears, and degenerative meniscus (264 meniscal sites); ligament injury (ACL; PCL; MCI; and LCL; 132 ligament sites); bone bruise; effusion; fracture and/or osteochondral defect. Lumbar spine reports were analysed for disc morphology (bulge, protrusion, extrusion and/or annular tear—180 intervertebral disc levels); degenerative disc disease; Modic endplate changes; cord compression; spinal stenosis; nerve root involvement; vertebral collapse, primary tumour or metastases; and other incidental findings. IAM reports were analysed for acoustic neuroma and vascular loop.

Agreement in the knee reports varied mainly between moderate ($\kappa = 0.46$) for ligament injury to very good [almost perfect] ($\kappa = 0.86$) for meniscal tears, although agreement for degenerative meniscus was only fair ($\kappa = 0.3$). Variation in the lumbar spine reports ranged predominantly between moderate ($\kappa = 0.54$) for disc bulge/protrusion to fair ($\kappa = 0.32$) for Modic endplate changes to good [substantial] ($\kappa = 0.79$) for tumour/metastases. Agreement for the presence of acoustic neuroma was very good [almost perfect] ($\kappa = 1.0$). Forty cases demonstrating the least variation were then selected and included in an objective structured examination (OSE) and used for assessing the radiographers' competence at the end of the education programme.

In study done by Lockwood, P (2015) under the title of **AFROC analysis of reporting radiographer's performance in MRI head interpretation.**

The aim of this research was to assess the diagnostic performance of a limited group of reporting radiographers and consultant radiologists in

clinical practice undertaking computed tomography (CT) head interpretation.

A multiple reader multiple case (MRMC) alternative free response receiver operating characteristic (AFROC) methodology was applied. Utilizing an image bank of 30 MRI head examinations, with a 1:1 ratio of normal to abnormal cases. A reference standard was established by double reporting the original reports using two additional independent consultant radiologists with arbitration of discordance by the researcher. Twelve observers from six southern National Health Service (NHS) trusts were invited to participate. The results were compared for accuracy, agreement, sensitivity, specificity. Data analysis used AFROC and area under the curve (AUC) with standard error.

The reporting radiographers results demonstrated a mean sensitivity rate of 88.7%, specificity 95.6% and accuracy of 92.2%. The consultant radiologists mean sensitivity rate was 83.35%, specificity 90% and accuracy of 86.65%. Observer performance between the two groups was compared with AFROC, AUC, and standard error analysis. (Lockwood, P. 2015

In study done by F A Gallagher et al in UK (2011) under the title of **Comparing the accuracy of initial head MRI reporting by radiologists, radiology trainees, neuroradiology technologists and emergency doctors.**

The aim of this study was to assess whether it is appropriate for nonradiologists to report head CTs by comparing the misreporting rates of those who regularly report head CTs with two groups of non-radiologists who do not usually report them: neuroradiology technologists and emergency doctors.

62 candidates were asked to report 30 head CTs, two-thirds of which were abnormal, and the results were compared by non-parametric statistical analysis. There was no evidence of a difference in the score between neuroradiology technologists, neuroradiologists and general consultant radiologists.

Neuroradiology technologists scored significantly higher than senior radiology trainees, and the emergency doctors scored least well. (Gallagher, et al. 2011)

Chapter three

Material and method

3.1 Material:

3.1.1 Head MRI cases:

30 admission head MRI will be chosen from patients who presented to the MRI department of Doctor`s Clinic Hospital and Al-Amal National Hospital in 3 months period.

20 of these films showed cranial abnormalities and 10 of them will be normal.

The cases will be chosen by a senior consultant radiologist. Films will be only included in the study if the abnormality was considered obvious on CT; only films reported by this senior consultant radiologist will be chosen to avoid bias by one of the candidates in the test.

Importantly, all abnormal films will be chosen to demonstrate conditions that could result in significant clinical adverse effects if missed on imaging. Before inclusion in the study, the diagnosis in each case will be confirmed, other clinical features, where available.

The remaining 10 films will be included in the test as “normal” cases but only considered for this category if patients had no significant neurological deficit, the films will be considered definitely normal by a senior radiologist. such studies will be performed for minor head trauma or headache.

Table 3.1: Shows the frequency of cranial MRI cases used in study

Final diagnosis	Frequency	Final diagnosis	Frequency
Normal	10	Ischemic Changes	2
Subdural Hemorrhage	2	AVM	1
Encephalitis	1	Acute Infarction	1
Sinusitis	1	MS	1
Glioma	1	Abscess	1
Meningioma	1	Hydrocephalus	1
Mets	1	Age Related Changes	1
Glioblastoma	1	Epilepsy	1
Chronic Infarction	3		
Total		30	

3.1.2 Candidates:

A total of 20 candidates will be engaged: 20 radiology technologists from different Corporations, different work experience (10 have experience more than 5 years, 8 less than 5 years and 2 have no experience), peripheral image interpretation courses (10 of them don't have courses) and some of them have MSc degree on Diagnostic Radiologic Technology (12 of them have MSc).

3.2 Methods

3.2.1 Head MRI test

A single file of Microsoft power point for all cases will be shown to the candidates in appropriate viewing conditions.

All images will be presented for each case with clinical data was written on the MRI request.

Age of the patients will be in range of 1–85 years and the candidates will be asked to review the cases within 2 hours. They will be instructed that some cases normal. If the candidate identified a case as abnormal, he or she was

asked to state in a few words what the abnormality or diagnosis was. The maximum score on the examination was 30.

3.2.2 Data analysis:

Statistics package for social sciences SPSS, Microsoft word and Excel will be used.

3.2.3 Ethical issues:

No patient data will be published also the data was kept in personal computer with personal password. Also, no patient asked to do MRI examination for the purpose of research.

Chapter four Results

Table (4.1) shows general distribution of technologist score

	Frequency	Percent	Valid Percent	Cumulative Percent
TP	281	46.8	46.9	46.9
TN	188	31.3	31.4	78.3
FP	100	16.7	16.7	95.0
FN	30	5.0	5.0	100.0
Total		100.0	100.0	
Over all Sensitivity = 90.3 %				
Over all Specificity = 65.2 %				
Over all Accuracy = 59.9 %				

TP= True Positive. TN= True Negative. FP= False Positive FN= False Negative.

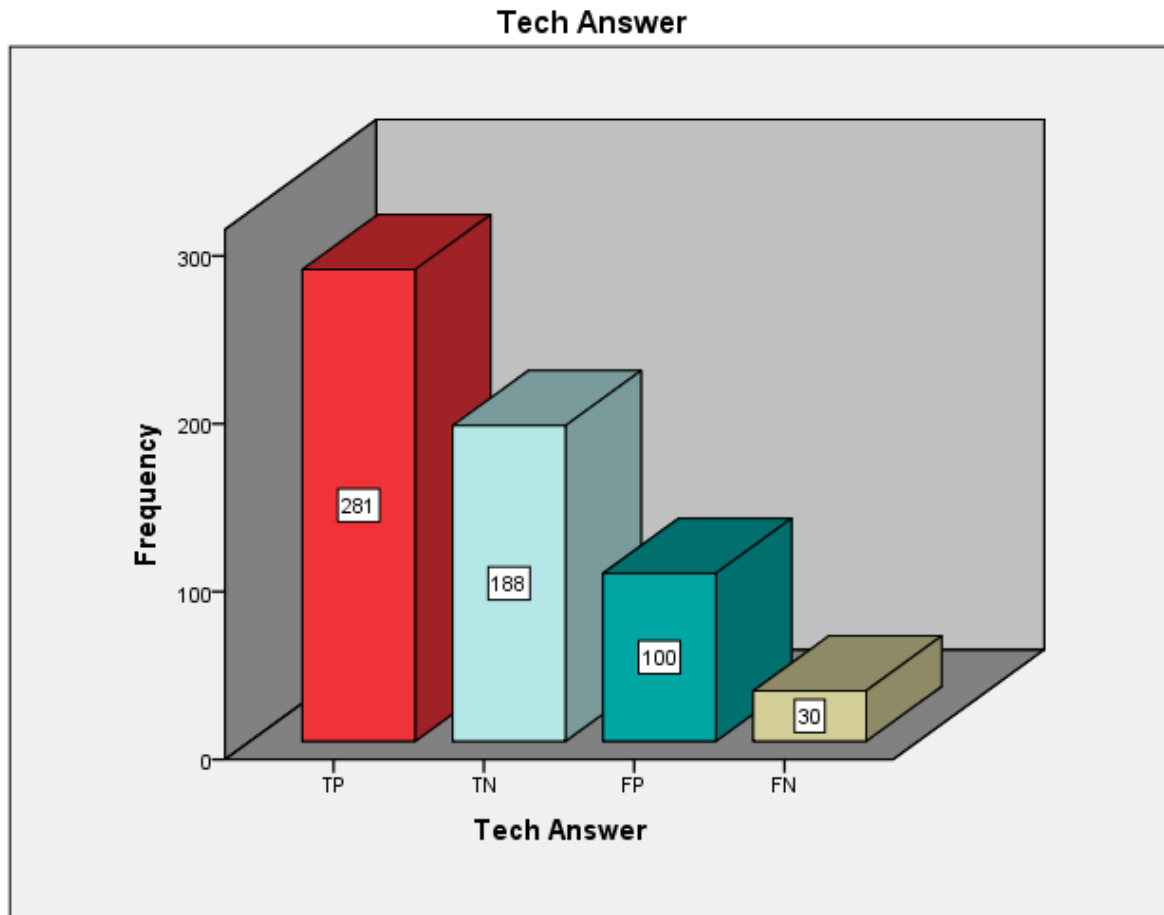


Figure (4.1): shows general distribution of technologist score

Table (4-2) the **Percentage** of the radiography specialist diagnosis performance

Diagnosis	Percentage %
Normal	93.3%
Subdural Hemorrhage	100%
Encephalitis	87%
Sinusitis	100%
Tumor	100%
Infarction	95.6%
Ischemic Changes	96.2%
AVM	90.9%
Acute Infarction	100%
MS	100%
Abscess	92.9%
Hydrocephalus	100%
Age Related Changes	100%
Epilepsy	0%
Accuracy	90.2%

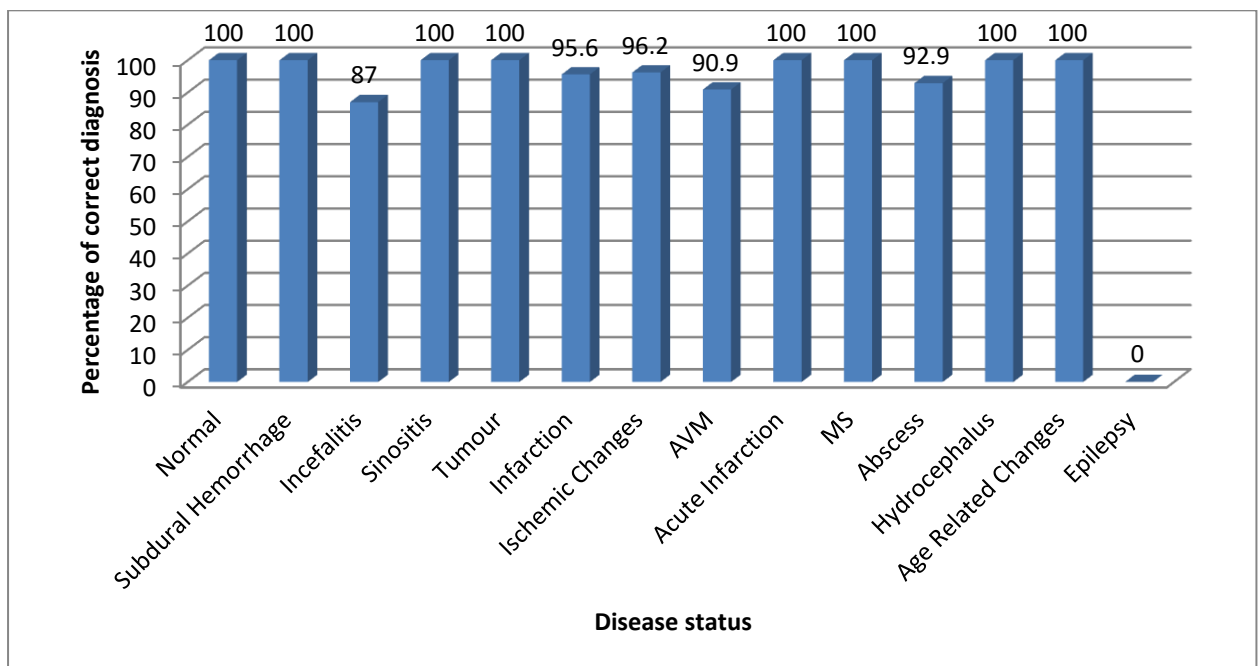


Figure 4-2 a bar graph portrayed the score of diagnosis for radiography specialist.

Table (4.3): shows the relation between technologist score and type of disease.

			Tech Answer				Total
			TP	TN	FP	FN	
Disease Type	Normal	Count	1	187	11	1	200
		% within Disease Type	0.5%	93.5%	5.5%	0.5%	100.0%
	Trauma	Count	40	0	0	0	40
		% within Disease Type	100.0%	0.0%	0.0%	0.0%	100.0%
	Inflammatory	Count	49	0	23	8	80
		% within Disease Type	61.2%	0.0%	28.8%	10.0%	100.0%
	Tumour	Count	56	0	24	0	80
		% within Disease Type	70.0%	0.0%	30.0%	0.0%	100.0%
	Vascular	Count	102	0	33	5	140
		% within Disease Type	72.9%	0.0%	23.6%	3.6%	100.0%
	Other	Count	33	1	9	16	59
		% within Disease Type	55.9%	1.7%	15.3%	27.1%	100.0%
	Total	Count	281	188	100	30	599
		% within Disease Type	46.9%	31.4%	16.7%	5.0%	100.0%
Accuracy in normal cases = 93%							
Accuracy in trauma cases = 100%							
Accuracy in Inflammatory cases = 61.2%							
Accuracy in tumor cases = 70%							
Accuracy in vascular cases = 72%							
Accuracy in other cases = 55.9%							
P value: 0.00							

TP= True Positive. TN= True Negative. FP= False Positive FN= False Negative.

Table (4.4): shows the relation between technologist score and work experience.

			Tech Answer				Total
			TP	TN	FP	FN	
Tech Experience	0 - 5	Count	170	116	53	21	360
		% within Tech Experience	47.2%	32.2%	14.7%	5.8%	100.0%
	5 - 10	Count	71	49	23	6	149
		% within Tech Experience	47.7%	32.9%	15.4%	4.0%	100.0%
	More than 10	Count	40	23	24	3	90
		% within Tech Experience	44.4%	25.6%	26.7%	3.3%	100.0%
Total		Count	281	188	100	30	599
		% within Tech Experience	46.9%	31.4%	16.7%	5.0%	100.0%
Accuracy with 0 - 5 Y experience = 59.4 %							
Accuracy with 5 - 10 Y experience = 59.1 %							
Accuracy with more than 10Y or more experience = 83.3 %							
P value: 0.00							

TP= True Positive. TN= True Negative. FP= False Positive FN= False Negative.

Table (4.5): shows the relation between technologist score and MSc degree in Diagnostic Radiologic Technology taken by technologist.

			Tech Answer				Total
			TP	TN	FP	FN	
MSc	No	Count	84	59	30	6	179
		% within MSc	46.9%	33.0%	16.8%	3.4%	100.0%
	Yes	Count	197	129	70	24	420
		% within MSc	46.9%	30.7%	16.7%	5.7%	100.0%
Total		Count	281	188	100	30	599
		% within MSc	46.9%	31.4%	16.7%	5.0%	100.0%
Accuracy with MSc = 60.4 %							
Accuracy without MSc = 58.1 %							
P value: 0.56							

TP= True Positive. TN= True Negative. FP= False Positive FN= False Negative.

Chapter five

Discussion, Conclusion and Recommendations

5.1 Discussion

The aim of this study was to determine the accuracy of 20 radiology technologist image interpretation in different 30 cranial MRI and to correlate the result with work experience and postgraduate studies.

The cranial MRI cases were in different types of disease shown to candidates by Microsoft power point in 2 hours as time for interpretation. The candidates were in different work experience period and they have different postgraduate studies.

Radiology technologist shows over all accuracy of (59.9%) with sensitivity of (90.3 %) and Over all Specificity by (65.2%) shown in (table 4.1) the result was lower than the first previous study (sensitivity 99%, specificity 99% and accuracy 89.2%) because of different education system.

The accuracy of radiology technologist image interpretation affected by different factors such as experience and image interpretation courses taken by them.

Firstly, the highest accuracy of radiology technologist image interpretation according to type of disease was in trauma (100%) because technologist involved in image interpretation by request from emergency doctors when the radiologist not available. The lowest accuracy was in inflammatory cases (61.2%) because it is mainly interpreted by radiologist. Table (4.3).

The technologist with higher work experience have scored more than others with no or lower experience the highest image interpretation accuracy in whom working 10 years or more (83.3%) also there is significant relationship between the experience and score (P value = 0.00) as shown in table (4.4).

The Diagnostic Radiologic Technology MSc program has mild effect on radiology technologist image interpretation accuracy (with M.Sc. (60.4%) with

no (58.1%). there is no significant relationship or difference in accuracy (P value = 0.56) as shown in table (4.5) that because the program mainly concentrates on technology more than clinical subjects.

5.2 Conclusion:

The study shows radiology technologist image interpretation accuracy in Sudan is 59.9% increases with clinical practice and diagnostic radiologic technology M.Sc. programme. The accuracy less than the accuracy shown in first study.

5.3 Recommendations:

From the previous results the study recommends that:

- Increase the training centers in Sudan and include the technologist in reporting process (skill mixing program).
- More studies in Sudan about radiology technologist image interpretation with different factors.
- More image interpretation subjects on formal education that increases the efficiency in image interpretation.

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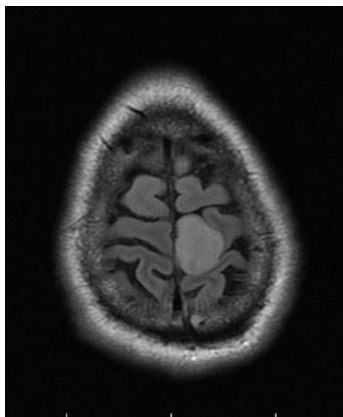
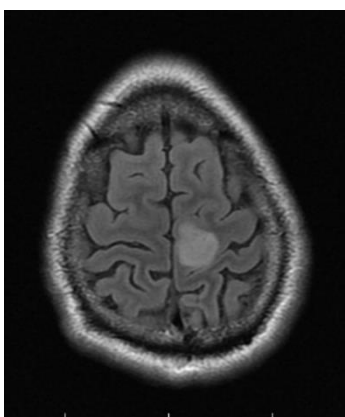
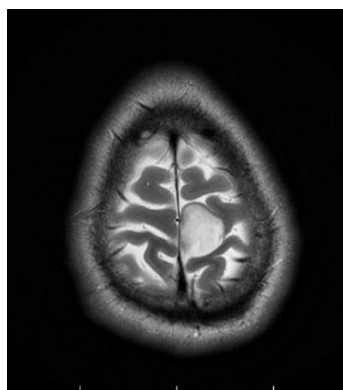
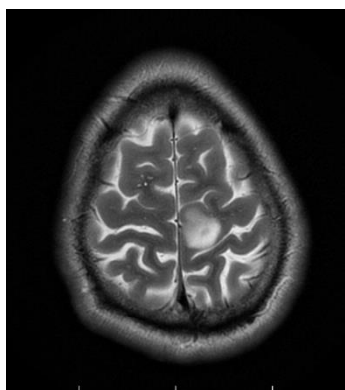
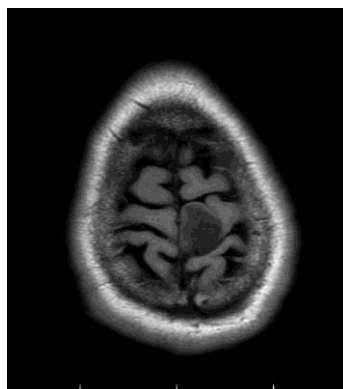
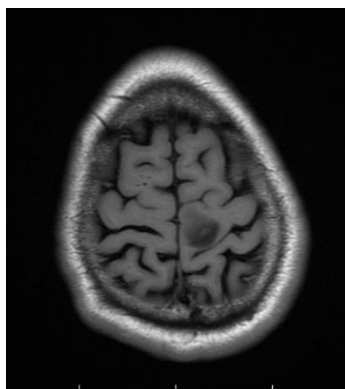
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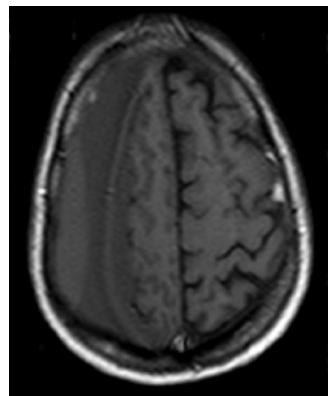
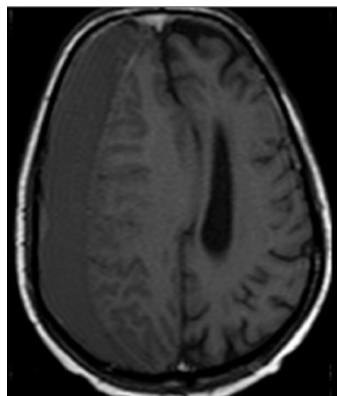
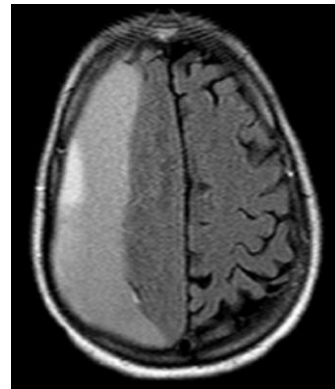
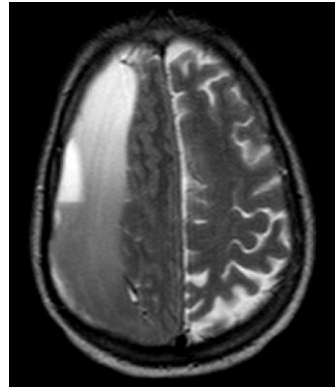
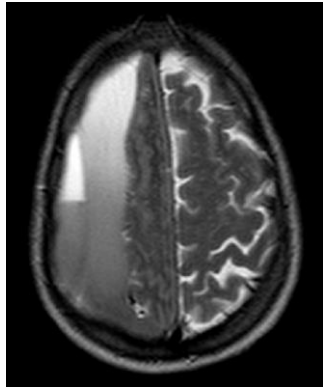
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Appendix

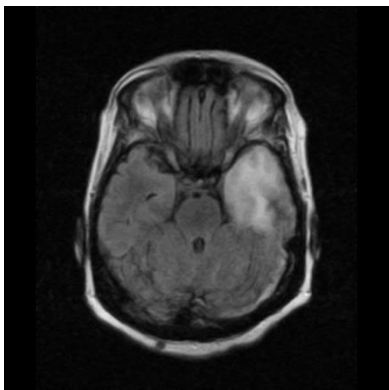
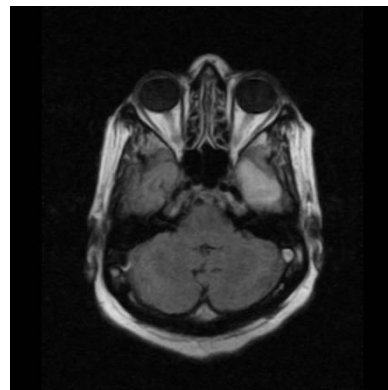
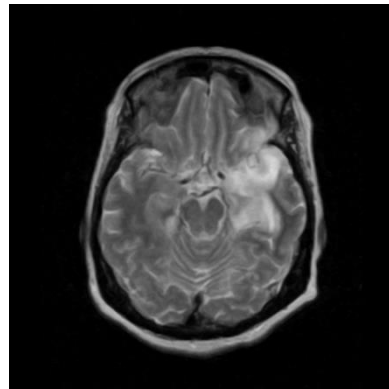
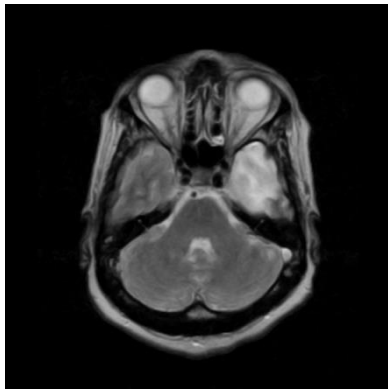
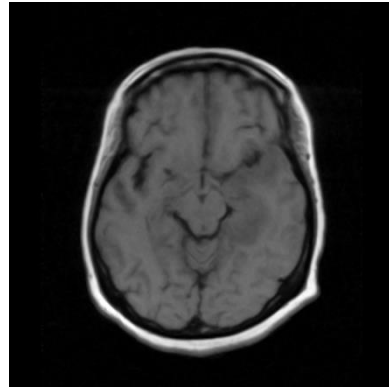
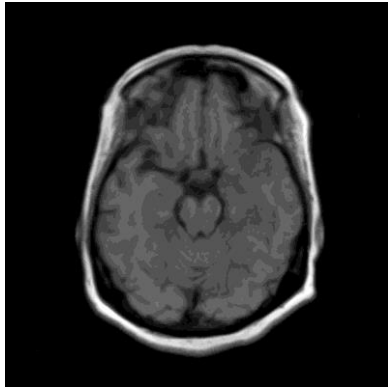
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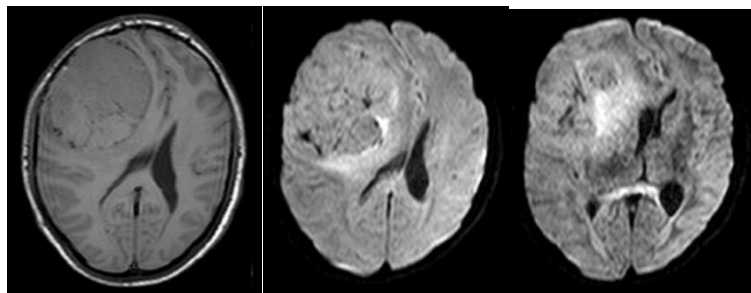
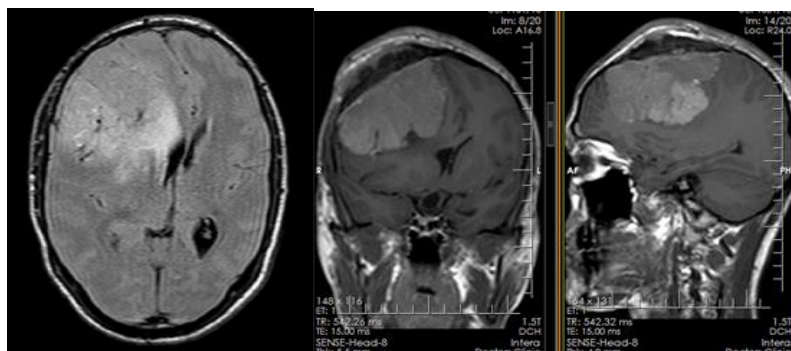
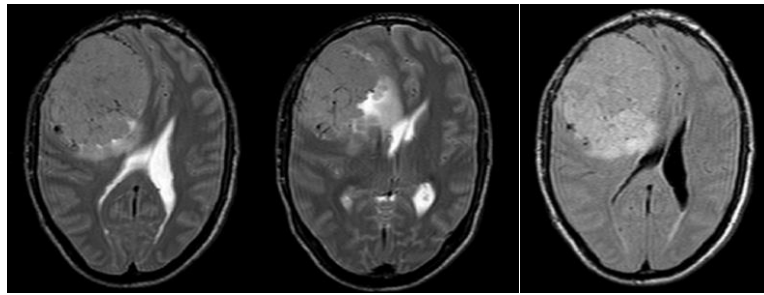
Case no (2) 61 years male with MRI Images Subdural



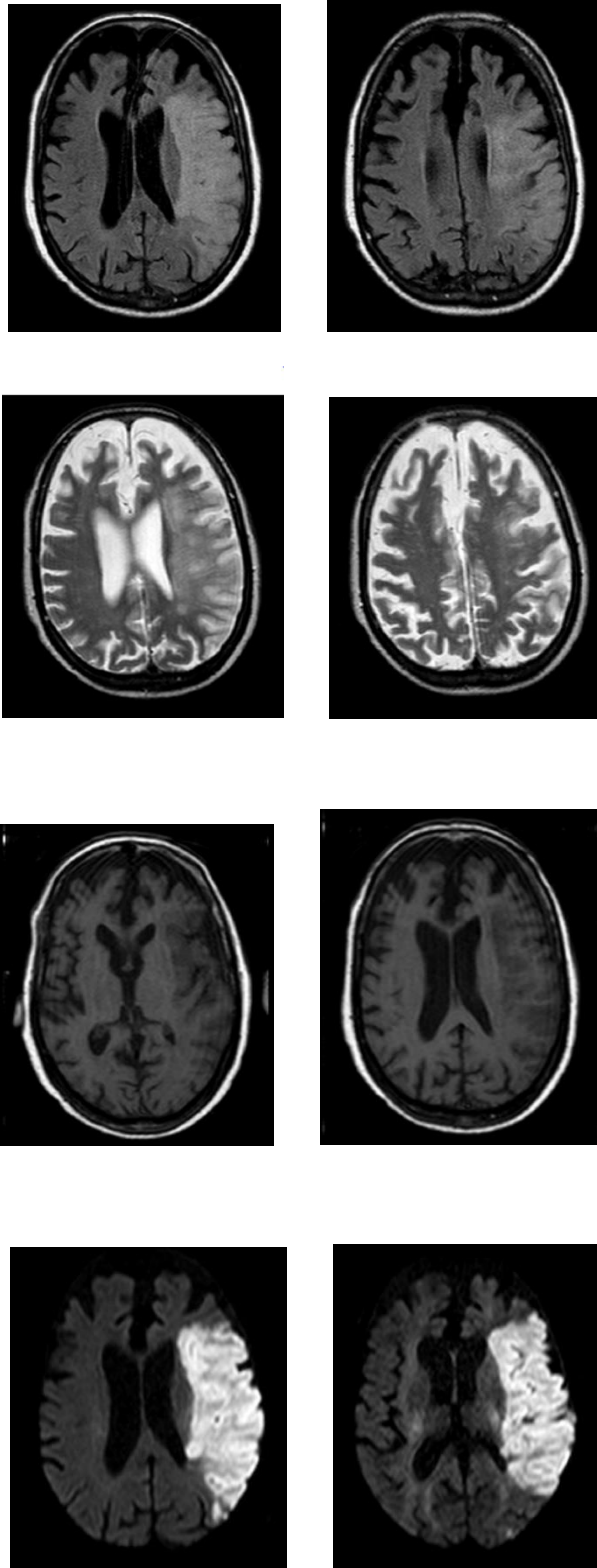
Case No. 3: 55 years with MRI Images Female Encephalitis



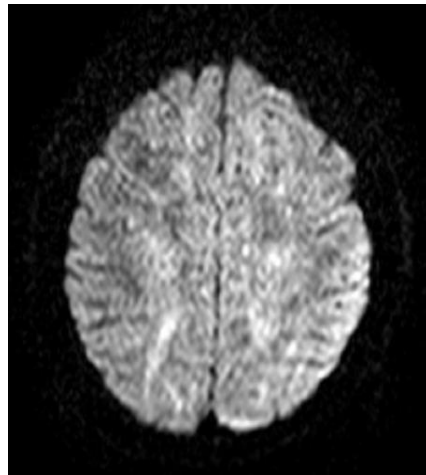
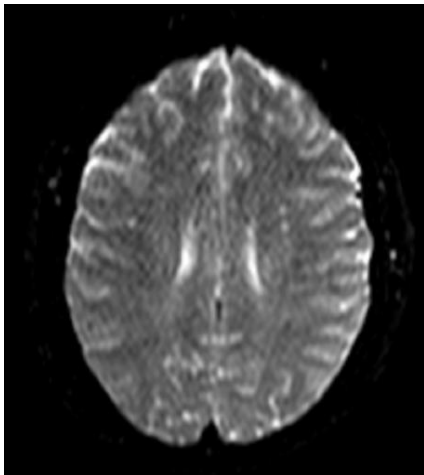
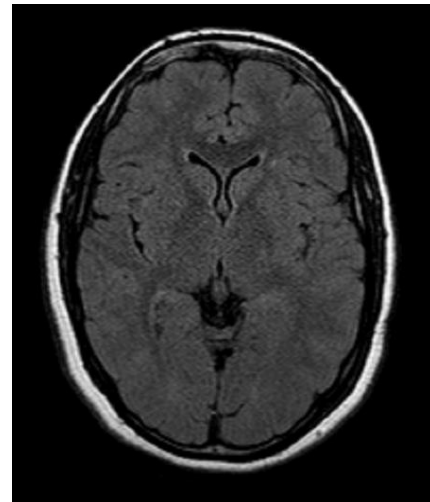
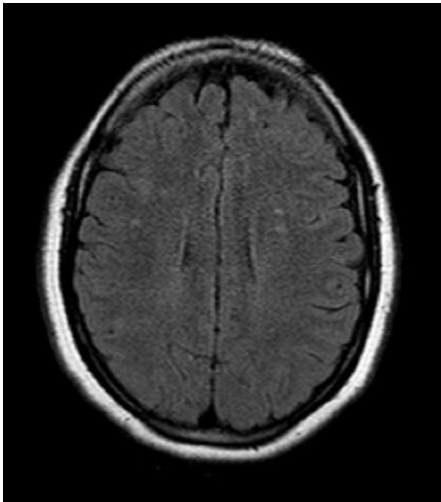
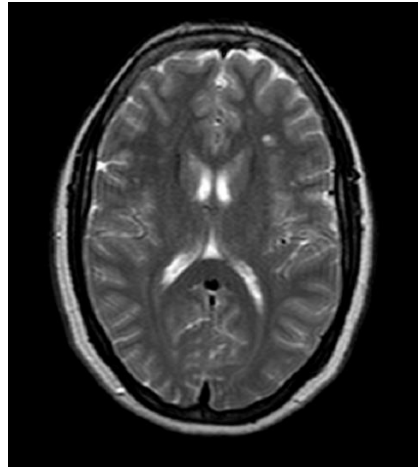
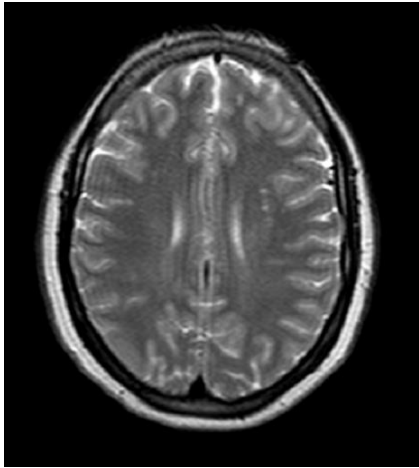
Case No. 4: 47 years male with MRI Images meningioma



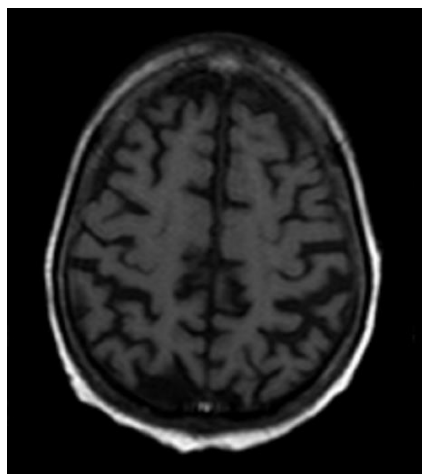
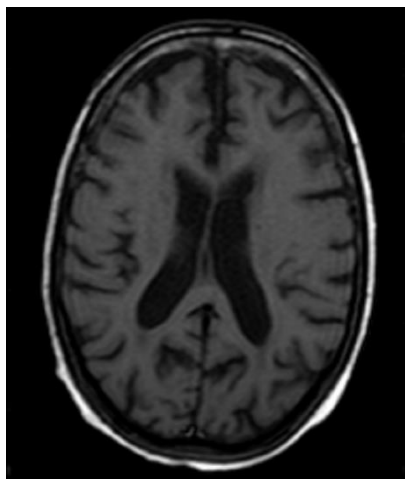
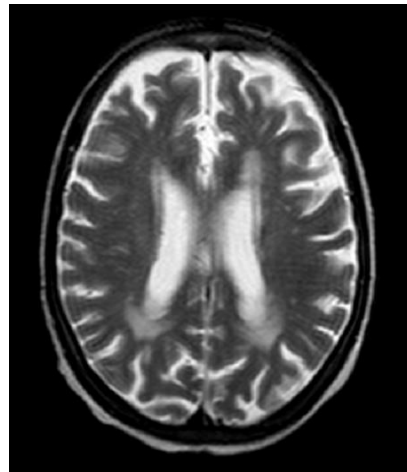
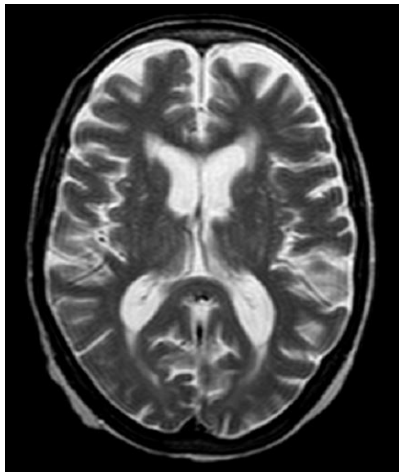
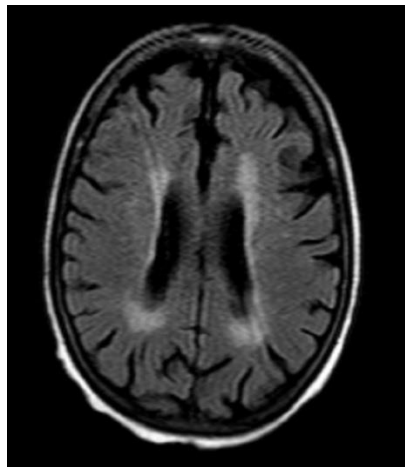
Case No. 5: 66 years male with MRI Images infarction



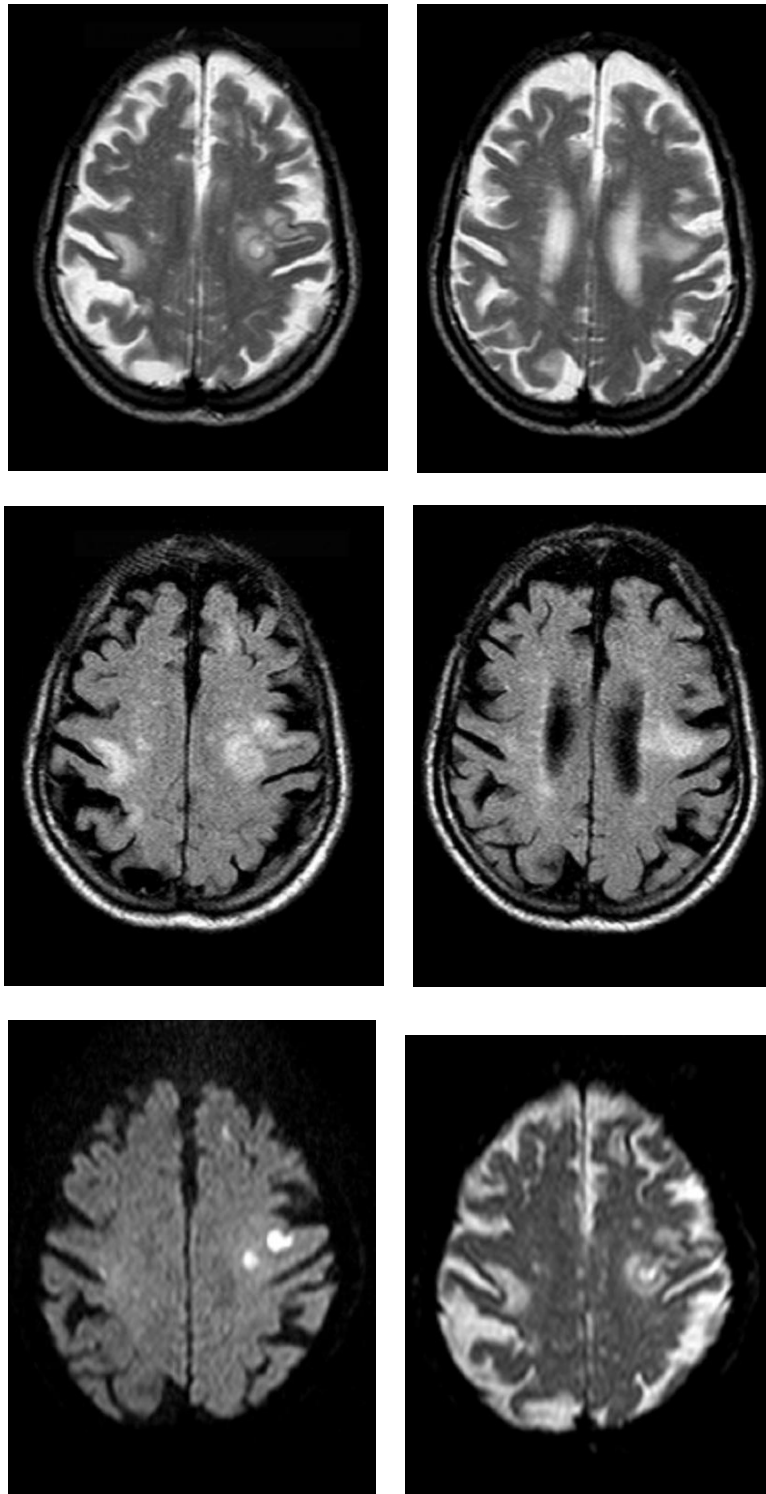
Case No. 6: 46 years Female with Multiple Sclerosis



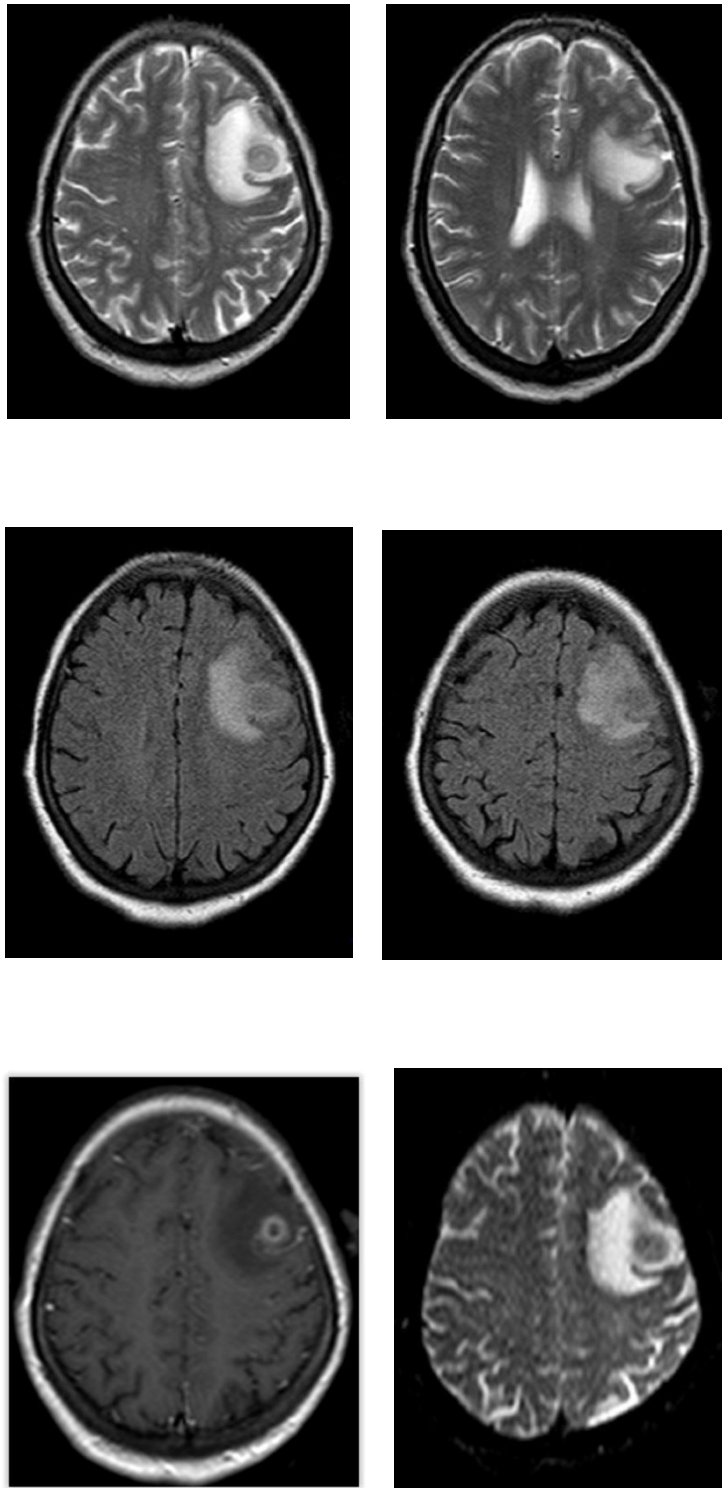
Case no. 7: 66 years Female with MRI Images Age Related Changes



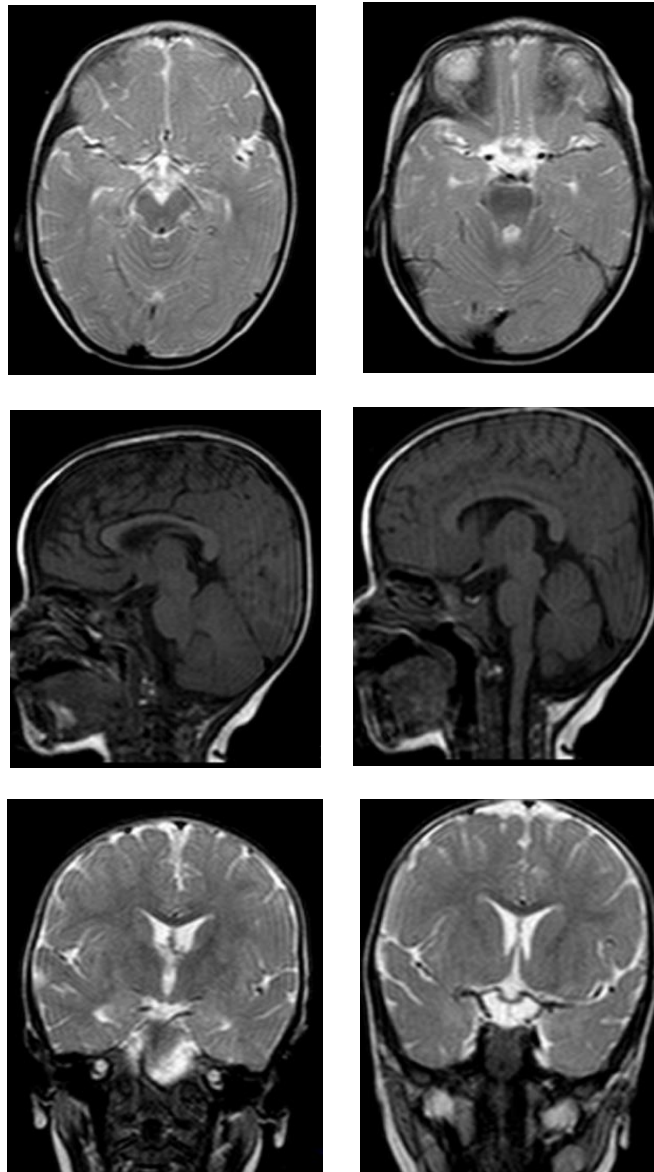
Case No. 8: 74 years male show MRI Images METs



Case No. 9: 61 years Female with MRI Images Abscess



Case No. 10: 1 year male with MRI images Epilepsy



Appendix (B)

Master data collection sheet was used in data collection and analysis

1. Patient:

A. ID #:

B. Gender:

C. Age:

D. complaints:

E. Referring department:

2. Technologist:

A.ID:

B. Opinion:

3. Final diagnosis by radiologist:

4. Type of disorder:

A. Congenital

B. Neoplasm

C. Vascular

D. Trauma

E. Inflammatory

F. Degenerative

G. Other