Sudan University of Science & Technology

College of Graduate Studies

Accuracy of Image Diagnosis by Radiology Technologist for Cranial Computed Tomography

دقة تشخيص الصور بواسطة تقني الأشعة للأشعة المقطعية القحفية

A thesis submitted in partial Fulfillment for the Requirement of MSc degree in Medical Diagnostic Radiography

By:

Omar Osman Mohammed Ahmed Mustafa

Supervisor:

Dr: Ikhlas Abdelaziz Hassan Mohamed

November 2016

Dedication

To my mother

the strongest person I know

I can't thank you enough for what you have done to

me. You were always there when I needed you the

most

To someone who gives the live meaning miss Amna

To everyone who searches for the knowledge

To everyone who wishes to me success.

With love and gratitude

Acknowledgement

staff of Al-Amal diagnostic center and Alzytona hospital.

Abstract

Cranial computed tomography (CT) is replacing skull radiography in head trauma. Rapid diagnostic radiological opinions on these images may not always be available.

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

A retrospective 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 77.34% was achieved, with a sensitivity of (95.89%) and specificity of (59.74%). The study also found that the accuracy affected by work experience period and peripheral image interpretation courses taken by the technologist.

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

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

ملخص الدراسة

الأشعة المقطعية القحفية حلت محل الأشعة التقليدية للجمجمة في حالات الإصابة بالرأس. قد لا تكون الآراء التشخيصية الإشعاعية متوفرة دوما.

هدفت هذه الدراسة إلى تحديد دقة تشخيص الصور بواسطة تقني الأشعه في حالات الأشعة المقطعية القحفية المختلفة

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

تم تحقيق دقة تشخيص شامة بمقدار 77.34% مع حساسية بمقدار 95.89% وخصوصية بمقدار 59.74%. 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 بإختلاف منهج التعليم والوصف الوظيفي للتقني

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

Table of Contents

List of tables

List of Figures

List of Abbreviations

CT	Computed tomography
ED	Emergency Department
A&E	Accident and emergency
FRCR	Fellowship of Royal College of Radiologist
SIGRR	Special Interest Group in Radiographer
CSF	Cerebral spinal fluid
MR	Magnetic resonance
AIDS	Acquired immunodeficiency syndrome
ACTH	Adrenocorticotropic hormone
TSH	Thyroid-stimulating hormone
AVM	Arteriovenous Malformation

Chapter one

1.Introduction

1.1 Introduction:

Radiology technologists worldwide are integral to the diagnostic pathway and are optimally placed to provide expert comment on radiographs. By nature, the radiology technologist is the first health care professional to view each diagnostic image, which has been acquired by a focus on the patient. 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 the potentially serious and costly consequences of an incorrect report; 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 seen 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:

The value of radiology technologist image diagnosis in Sudan haven't been estimated before.

1.3   Justification:

In Emergency Departments (ED) junior doctors regularly make critical diagnostic decisions based on CT head images. Also, many stats on Sudan need a professional interpretation of CT image, that they don't have it

1.4   Objectives of the study:

1.4.1 General objective:

To determine the accuracy of radiology technologist image diagnosis in cranial CT in clinical practice.

1.4.2 Specific objectives:

- To estimate radiology technologist image diagnosis sensitivity and specificity in detecting cranial abnormality.
- To estimate radiology technologist image diagnosis accuracy with deferent abnormalities.
- To correlate the results with radiology technologist experience, peripheral courses and postgraduate studies.

Chapter two

2. Theoretical review

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

4

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 feature 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)
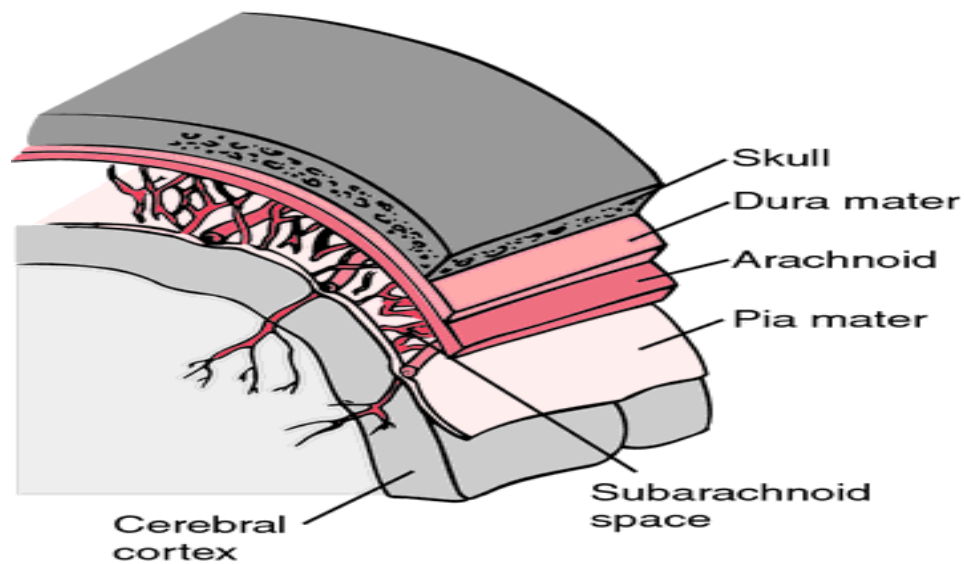

Figure (2.1): shows Meninges of the central nervous system. (The free dictionary, 2012).

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 fontal (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.

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.

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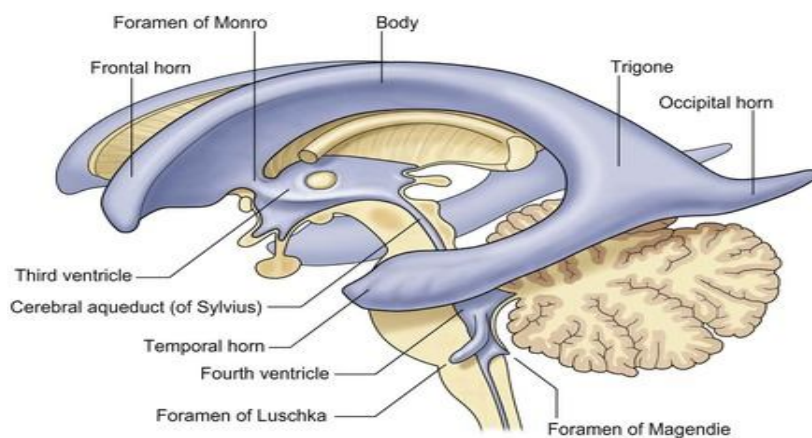
(Figure 2.2) Components of the ventricular system. (Radiology key, 2016)

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 CT 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 HeschI) gyri. The two main fissures of the cerebrum are the longitudinal fissure and the latera 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)
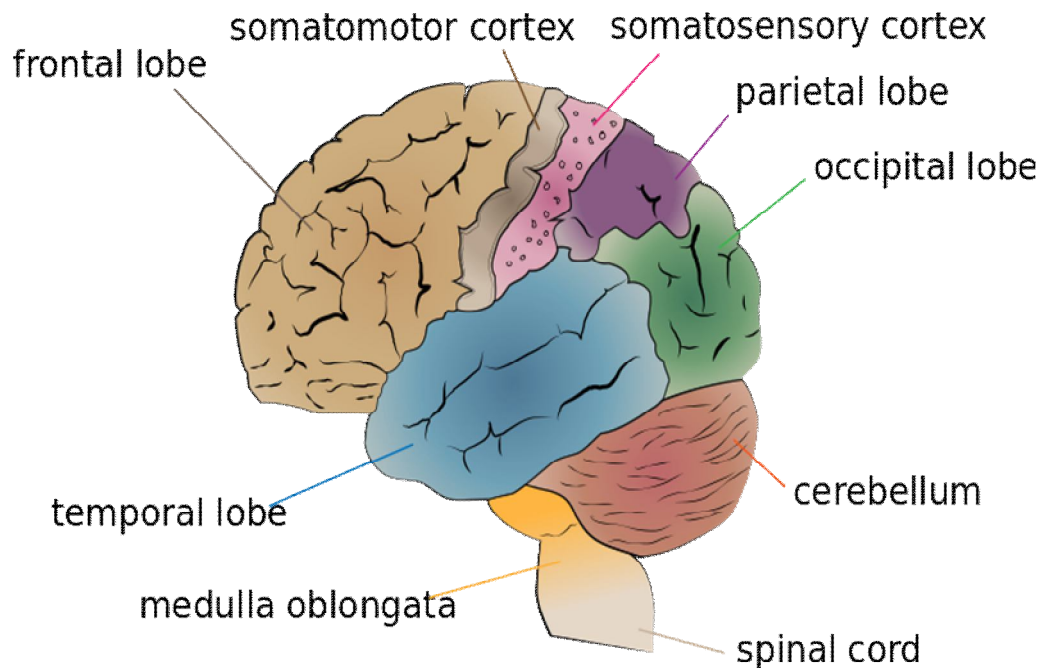
(Figure 2.3) Annotated lobes of the cerebrum. (Jkwchui, 2013)

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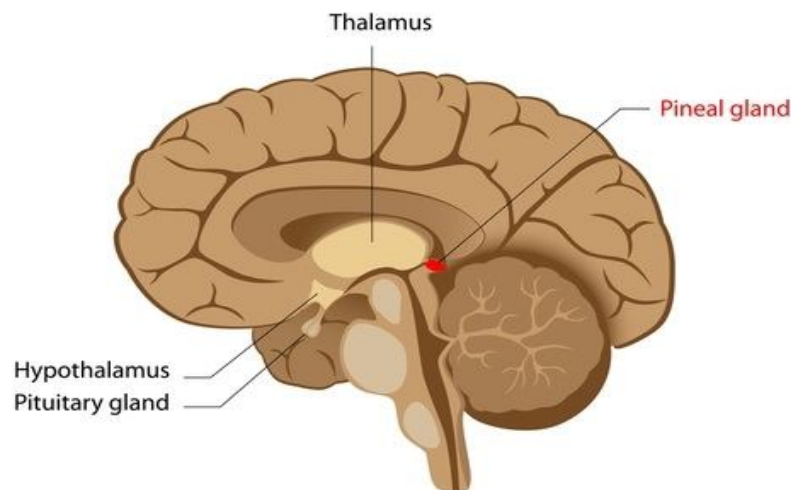
(**Figure 2.4**) The locations of the pineal gland, hypothalamus, thalamus and pituitary gland. (Alyvea, 2009)

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 f bres 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 sella (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)
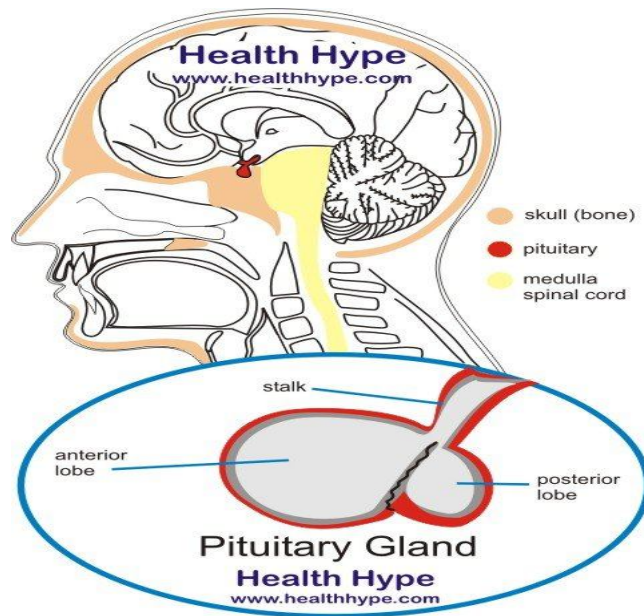

(Figure 2.5) shows Anterior and Posterior Pituitary. (Chris, 2016)

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)
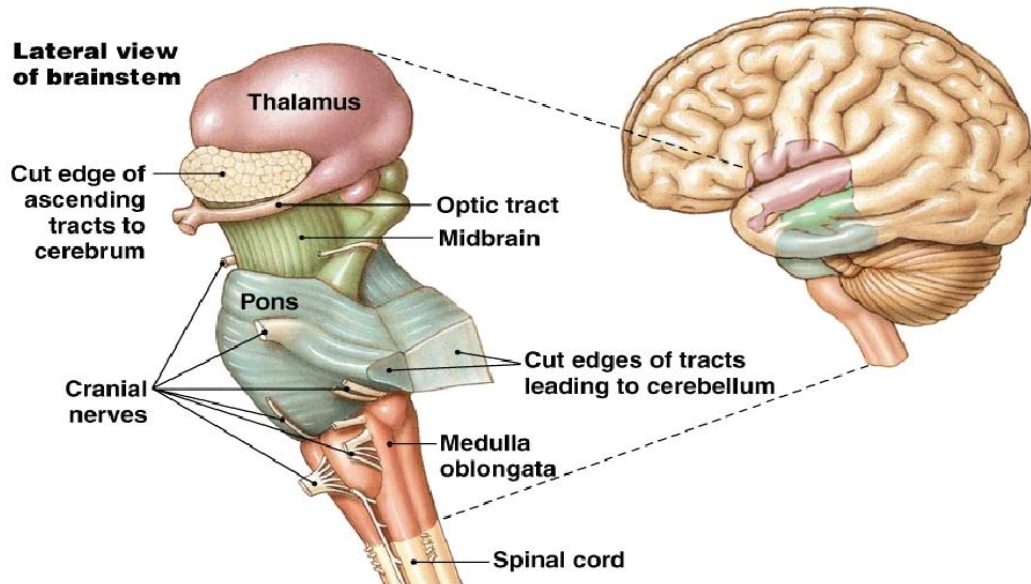

(Figure 2.6) Demonstrates Lateral view of brainstem. (cognitive consonance, 2015)

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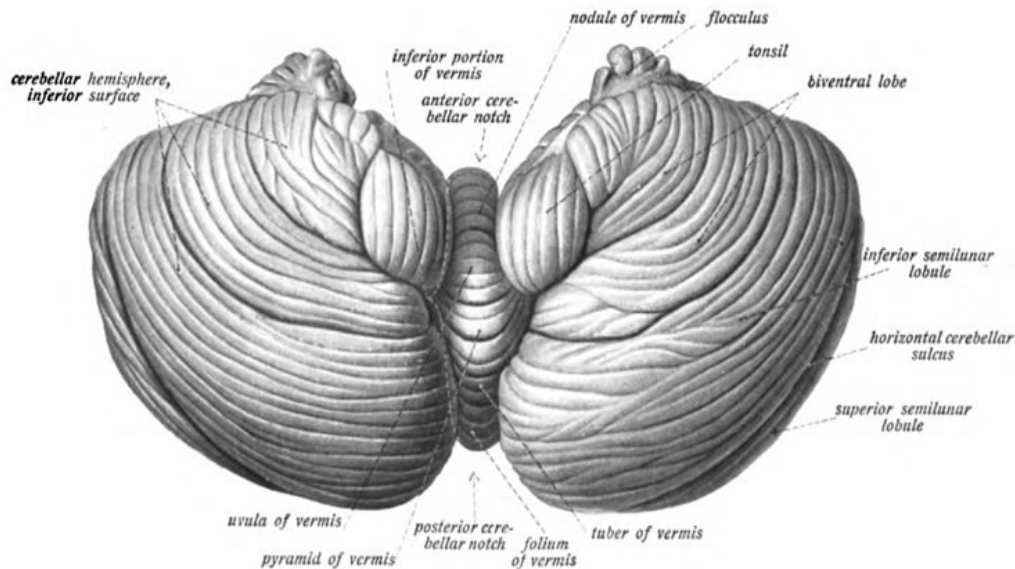
(Figure 2.7) Shows the structures of cerebellum. (Neuroscience news,2014)

2.3 Common Pathological conditions of brain:

2.3.1 Infectious diseases of brain:

2.3.1.1 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)

2.3.1.2 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)

2.3.1.3 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)

2.3.1.4 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)

2.3.1.5 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)

2.3.2 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)

2.3.2.1 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)

2.3.2.2 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)

2.3.2.3 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 adrenocorticotropic 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 adrenocorticotropic 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)

2.3.2.4 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)

2.3.3 Traumatic Processes of brain and skull:

2.3.3.1 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)

2.3.3.2 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)

2.3.4 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)

2.3.5 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)

2.3.6 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)

2.4 Previous studies:

2.4.1 First study:

Done by P. Lockwood, K. Piper, L. Pittock in UK (2014) under the title of **CT head reporting by radiology technologists: Results of an accredited postgraduate program**

The aim of this study was to evaluate the results of the summative objective structured examination (OSE) for the first four cohorts of radiology technologists (n ¼ 24) undertaking an accredited postgraduate course in reporting computed tomography (CT) head examinations.

The study included the construction of a summative OSE contained twenty-five CT head examinations that incorporated 1:1 normal to abnormal pathological examples. All cases were blind reported by three consultant radiologists to produce a valid reference standard report for comparison with the radiology technologist's interpretation. The radiology technologists (n ¼ 24) final reports (n ¼ 600) were analyzed to determine the sensitivity, specificity and agreement values and concordance for the four cohorts.

The four cohorts (2007e2013) of postgraduate radiography students' collective OSE results established a mean sensitivity rate of 99%, specificity 95% and agreement concordance rates of 90%.

The final grades indicate that within an academic environment, trained radiology technologists possess high levels of diagnostic performance accuracy in the interpretation of CT head examinations. (Lockwood, et al., 2014)

2.4.2 Second study:

Done by F A Gallagher et al in UK (2011) under the title of **Comparing the accuracy of initial head CT 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)

2.4.3 Third study:

Done by Lockwood, P (2015) under the title of **AFROC analysis of reporting radiographer's performance in CT 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 CT 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)

Chapter three

3.Material and methods

3.1   Material:

3.1.1 Head CT cases:

30 admission head CTs were chosen from patients who presented to the CT department of Al-Amal National Hospital and Alzaytouna hospital in 3 months period.

20 of these films showed cranial abnormalities and 10 of them were normal these are listed in Table 3.1. In order to maximize the difference in the outcome of the test between the various groups of candidates, some difficult films were deliberately selected.

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

Importantly, all abnormal films were 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 was confirmed, other clinical features, where available.

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

Final diagnosis	Frequency	Final diagnosis	Frequency
Normal	10	AVM	1
basal ganglia hemorrhage	1	Acute Infarction	1
Subdural hematoma	2	Encephalitis	1
Aneurysm	1	Glioma	1
Acoustic Neuroma	1	Epidural hematoma	1
Arachnoid Cyst	1	Old infarction	3
Metastatic Carcinoma	1	Osteoma	1
Subarachnoid hemorrhage	1	Skull fracture	1
F. B	1	Acute Infarction	1
basal ganglia hemorrhage	1	Subdural hematoma	2
Total		**30**	

Table (3.1): Shows the frequency of cranial CT cases used in study

3.1.2 Candidates:

A total of 20 candidates were 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 CT test

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

All images were presented for each case with clinical data was written on the CT request.

Age of the patients were in range of 1–85 years and the candidates were asked to review the cases within 2 hours. They were instructed that some cases were 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

The statistical analysis were carried out using the SPSS software package (V20.0; SPSS Inc., Chicago, IL). Data analyzed by Chi-Square Tests and cross tabulation.

Accuracy, sensitivity and specificity were measured. By the following equations:

- sensitivity = TPF = TP/(TP + FN)*100
- Specificity = TNF = TN/(TN + FP)*100
- Accuracy = [(TP+TN)/(TP+FP+TN+FN)] *100

TP ≡ True Positive. TN ≡ True Negative.

FP ≡ False Positive FN ≡ False Negative.

3.3 Ethical issues:

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

Chapter Four

4. Results

Table (4.1) shows general distribution of technologist score

	Frequency	Percent	Valid Percent	Cumulative Percent
TP	280	46.7	46.7	46.7
TN	184	30.7	30.7	77.3
FP	124	20.7	20.7	98.0
FN	12	2.0	2.0	100.0
Total	600	100.0	100.0	
Over all sensitivity = 95.89 %				
Over all Specificity = 59.74%				
Over all accuracy = 77.34%				

TP= True Positive. TN= True Negative. FP= False Positive FN= False Negative.
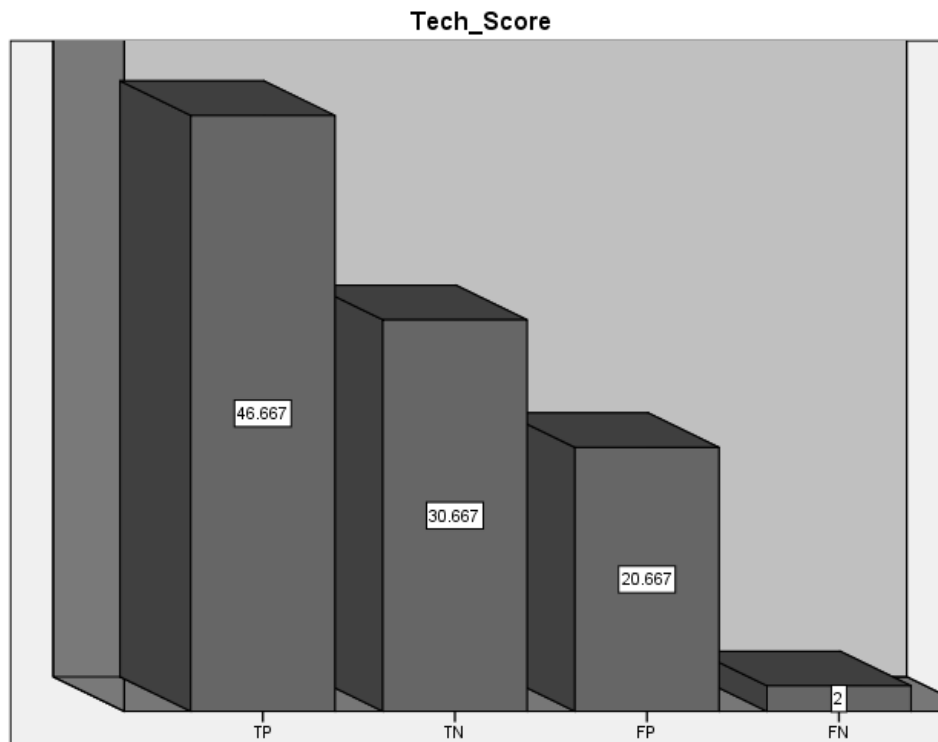
Figure (4.1): shows general distribution of technologist score

Table (4.2):shows the relation between technologist score and type of disease.

	TP	TN	FP	FN	Total
Trauma	92 (92%)	0 (0%)	6 (6%)	2 (2%)	100 (100%)
Tumor	50 (50%)	0 (0%)	50 (50%)	0 (0%)	100 (100%)
Vascular	128 (71.1%)	0 (0%)	42 (23.3%)	10 (5.6%)	180 (100.0%)
Inflammatory	10 (50.0%)	0 (0%)	10 (50%)	0 (0%)	20 (100%)
None	0 (0%)	184 (92%)	16 (8%)	0 (0%)	200 (100%)
Total	280 (46.7%)	184(30.7%)	124(20.7%)	12 (2%)	600 (100%)
Accuracy in trauma cases = 92%					
Accuracy in tumor cases = 50%					
Accuracy in vascular cases = 71.1%					
Accuracy in Inflammatory cases = 50%					
Accuracy in normal cases = 92%					
P value: 0.00					

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

Table (4.3): shows the relation between technologist score and work experience.

	TP	TN	FP	FN	Total
None	18 (30%)	14 (23.3%)	28 (46.7%)	0 (0%)	60 (100%)
Less than 5Y	104(43.3%)	70 (29.2%)	62 (25.8%)	4 (1.7%)	240(100%)
5Y or more	158(52.7%)	100 (33.3%)	34 (11.3%)	8 (2.7%)	300(100%)
Total	280(46.7%)	184(30.7%)	124(20.7%)	12 (2%)	600(100%)
Accuracy without experience = 53.3%					
Accuracy with <5 Y experience = 72.5 %					
Accuracy with 5Y or more experience = 86 %					
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 peripheral image interpretation courses taken by technologist.

	TP	TN	FP	FN	Total
0 course	120 (40%)	84 (28%)	92 (30.7%)	4 (1.3%)	300 (100%)
1 course	54 (45%)	40 (33.3%)	18 (15%)	8 (6.7%)	120 (100%)
3 courses	38 (63.3%)	20 (33.3%)	2 (3.3%)	0 (0%)	60 (100%)
6 courses	30 (50%)	20 (33.3%)	1 0 (16.7%)	0 (0%)	60 (100%)
7 courses	38 (63.3%)	20 (33.3%)	2 (3.3%)	0 (0%)	60 (100%)
Total	280 (46.7%)	184 (30.7%)	124 (20.7%)	12 (2%)	600 (100%)
Accuracy without courses = 68 %					
Accuracy with one course = 78.3%					
Accuracy with three courses = 96.66%					
Accuracy with six courses = 83.33 %					
Accuracy with seven courses = 96.66%					
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.

	TP	TN	FP	FN	Total
Yes	168 (46.7%)	104 (28.9%)	84 (23.3%)	4 (1.1%)	360 (100%)
No	112 (46.7%)	80 (33.3%)	40 (16.7%)	8 (3.3%)	240 (100%)
Total	280 (46.7%)	184 (30.7%)	124 (20.7%)	12 (2%)	600 (100%)
Accuracy with MSc = 75.5%					
Accuracy without MSc = 80 %					
P value: 0.56					

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

Chapter five
5.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 CT and to correlate the result with work experience and postgraduate studies.

The cranial CT cases was 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 (77.34%) with sensitivity of (95.89 %) and Over all Specificity by (59.74%) shown in (table 4.1) the result was lower than the first previous study (sensitivity 99% and specificity 95%) 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 because technologist involved in image interpretation by request from emergency doctors when the radiologist not available. The lowest accuracy was in tumor and inflammatory cases because it is mainly interpreted by radiologist. Table (4.2).

The technologist with work experience have scored more than others with no experience the highest image interpretation accuracy in whom working 5 years or more (86%) also there is significant relationship between the experience and score (P value = 0.00) as shown in table (4.3).

On other hand the technologists who take courses in image interpretation have higher image interpretation accuracy than the others the highest accuracy recorded was (69.66%) and the lowest was (68%) recorded by the technologists who don't have this kind of courses also their significant relationship between the courses and the score (P value = 0.00) as shown in table (4.4).

The Diagnostic Radiologic Technology MSc program has no effect on radiology technologist image interpretation accuracy 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 77.34% increases with clinical practice and image interpretation courses. The accuracy less than UK as shown in first study.

5.3 Recommendations:

From the previous results the study recommend 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.

References:

- Alyvea 2009, Anatomy of the Human Head - Bones, Brain, Sensory Organs, digital image, accessed 4 November 2016, < http://www.alyvea-.com/biologystudyguides/humanskullandbrain.php >

- Berman L, de Lacey G, Craig O. (1985). A survey of accident and emergency reporting: results and implications. Clinical Radiology, 36 (483), 4.

- Berman L, de Lacey G, Twomey E, Twomey B, Welch T, Eban R. (1985). Reducing errors in the accident department: a simple method using radiographers. BMJ (Clinical Residents' ed.), 2(6466): 421.

- Callaway MP, Kay CL, Whitehouse RW. (1997). Fields JM. RAD Magazine, 2(266), 31.

- Canterbury Christ Church College Department of Radiography. (1995) Postgraduate Certificate in Radiography (Clinical Reporting). Appendicular and axial skeleton. Programme information, requirements and applications. Canterbury Christ Church College, Canterbury.

- Chapman AH. (1997) Changing work patterns. Lancet, 3(350). 581.

- College of Radiographers. (1997) Reporting by Radiographers; a Vision Paper. College of Radiographers, London.

- Cunningham DA.(1997). Special interest group in radiographer reporting. British Journal Radiology, 4(837), 873.

- De Lacey G, Barker A, Harper J, Wignall, B. (1980). An assessment of the clinical effects of reporting accident and emergency radiographs. . British Journal of Radiology, 53 (304). 9.

- Dellar, HJ, Haywood SC. (1970). The hospital radiographer—a profile. Radiography, 36(278), 80.

- Eisenberg, R, Johnson, N. (2012). Comprehensive radiographic Pathology. 5th edition. London: Elsevier, 290-337

- Gallagher, F. A. et al., 2011. Comparing the accuracy of initial head CT reporting by radiologists, radiology trainees, neuroradiology technologists and emergency doctors. The British Journal of Radiology, Issue 84, p. 1040– 1045.

- Irving HC. (1996). Skill-mix in clinical radiology. British Journal Hospital Medical, (77), 536.

- Kowalczyk, N. (2014). Radiographic pathology for technologists. 6th edition. London: Elsevier, 249-288

- Larkin G. Occupational monopoly and modern medicine. London, England: Tavistock, 1983

- Lockwood, P., Piper, K. & Pittock, L., 2014. CT head reporting by radiology technologists: Results of an accredited postgraduate programme. Radiography, Issue 21, pp. 85-89

- Lodwick, GS. (1968). The new image of diagnostic radiology. Radiology, 91(1045), 7.

- Lockwood, P. (2015). AFROC analysis of reporting radiographer's performance in CT head interpretation. Radiography,1(6),125.

- LORRIE, L, Connie, M. (2007). Sectional anatomy for imaging professionals.2nd edition. Philadelphia. Elsevier.87-124.

- Loughran CF. (1994) Reporting of fracture radiographs by radiographers: the impact of a training programme. British Journal of Radiology, 67, 945.

- Loughran CF.(1996) Reporting of accident radiographs by radiographers. RAD Magazine, 22(254), 34.

- Mucci B. (1983). The selective reporting of X-ray films from the accident and emergency department. Injury, 14 (343), 4.

- Price R. (1989). Education and training committee report—1988/9. Radiography Today, 9(630), 28.

- Robinson PJ. (1996) Short communication: plain film reporting by radiographers—a feasibility study. British Journal of Radiology, 69, 1171.

- Ryan, S. McNicholas, M. Eustace,S. (2011). Anatomy for Diagnostic Imaging.3rd edition. New York. Elsevier.60-65

- Saxton HM. (1992). Should radiologists report on every film?. Clinical Radiology, 45, 1–3.

- Shanks, SC. (1965). The duties of radiographers in special radiological examinations. Radiography, 31, 172

- Sherwood, T. (1975). Radiology now Choices. British Journal of Radiology, 48 (961), 2.

- Sutton, D. (2003). Textbook of radiology and imaging. 7th edition. London: Elsevier, 1730-1850

- Swinburne, K. (1971) Pattern recognition for radiographers. Lancet, 1(7699), 589.

- Swinburne, K.(1971). Pattern recognition for radiographers. Lancet, 1,589–590

- Wardrope, J, Chennells, PM. (1985). Should all casualty radiographs be reviewed?. BMJ (Clinical Residents, ed.), 290(6482), 40.

- Woznitza, N. (2014). Radiographer reporting. Journal of Medical Radiation Sciences, 61(2), 66–68. http://doi.org/10.1002/jmrs.51

- Chris 2016, Pituitary Gland Anatomy, Location, Hormones and Pictures, digital image, accessed 4 November 2016, < http://www.health-hype.com/pituitary-gland-function-and-pituitary-hormones.html >

- cognitive consonance 2015, Brainstem crossover point, digital image, accessed 4 November 2016, < http://cognitiveconsonance.info/tag-/brainstem-crossover-point/ >

- Jkwchui 2013, Annotated lobes of the cerebrum, digital image, accessed 4 November 2016, <http://training.seer.cancer.gov/module_anatomy/unit-5_3_nerve_org1_cns.html>

- Neuroscience news 2014, sobotta cerebellum autism, digital image, accessed 4 November 2016, < http://neurosciencenews.com/autism-cerebellar-damage-1285/sobotta-cerebellum-autism/ >

- Radiology key 2016, Overview of Anatomy, Pathology and Techniques; Aspects Related to Trauma, digital image, accessed 4 November 2016, <https://student.unsw.edu.au/citing-images-and-tables-found-online>

- The free dictionary 2012, meninges, digital image, accessed 4 November 2016, <http://medicaldictionary.thefreedictionary.com/meninges>.

Appendix (A)

Some cases used in estimation of radiology technologist image diagnosis
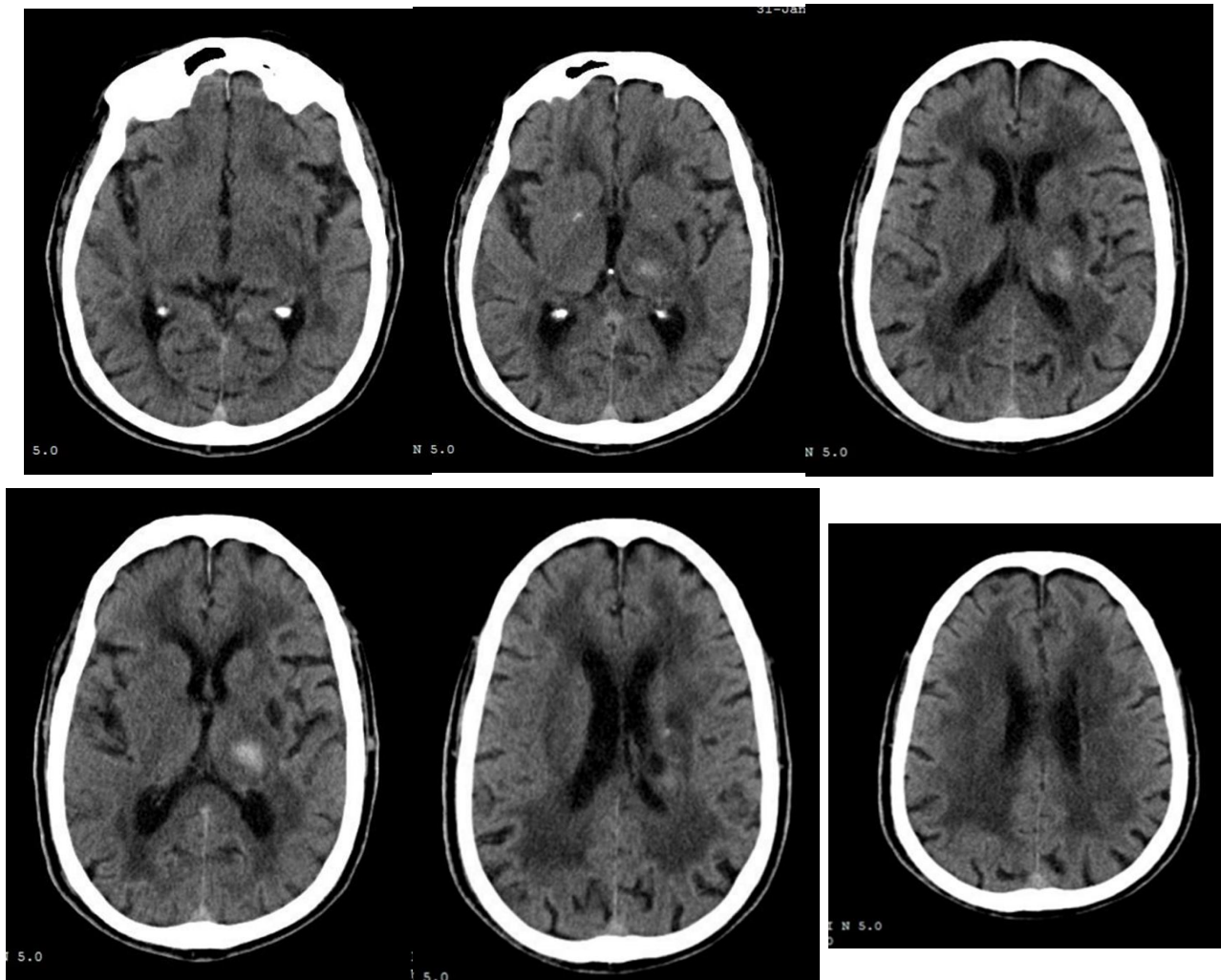
Case (1): 80Y old Male complain of right side weakness CT image shows
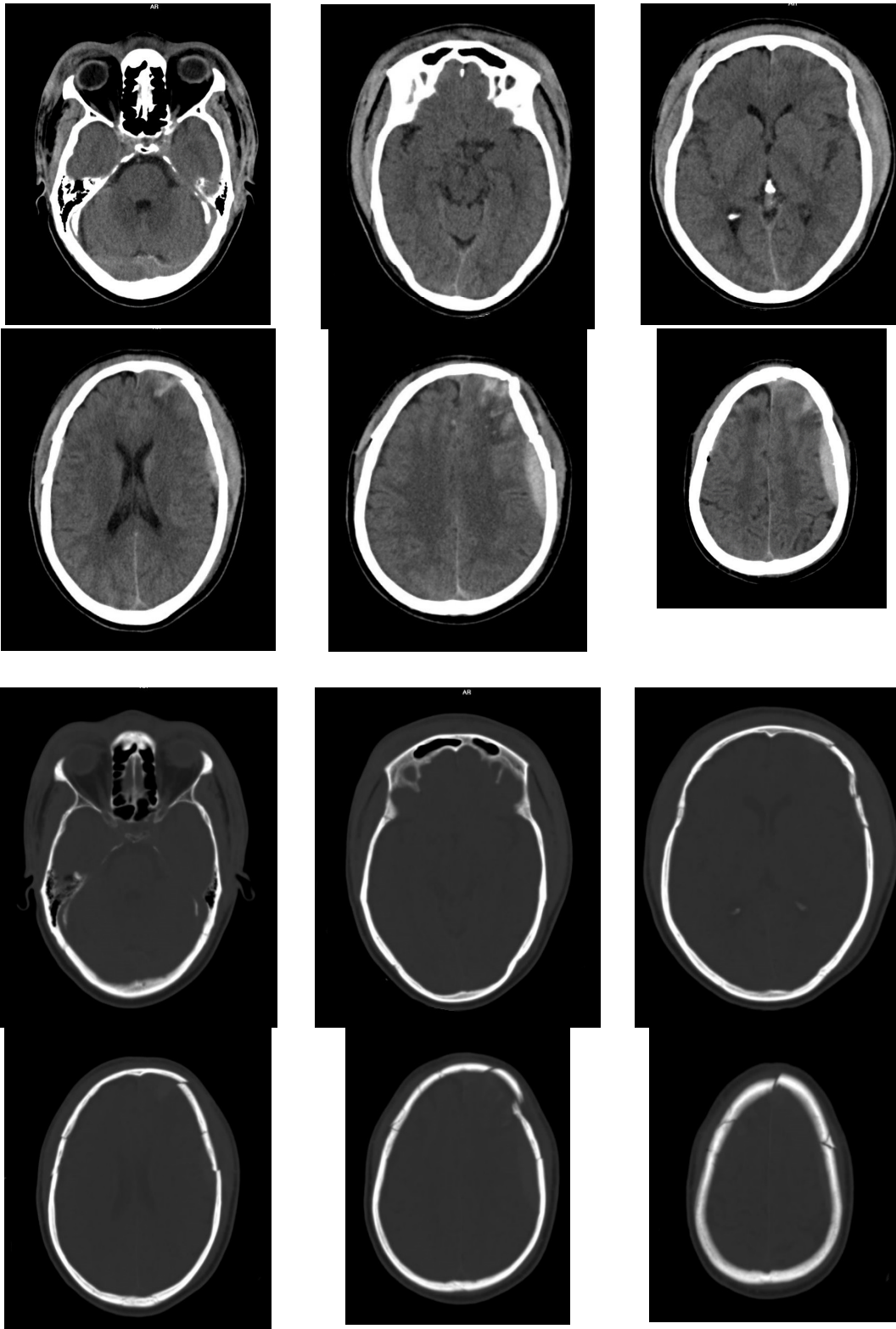
left side basal ganglia hemorrhage
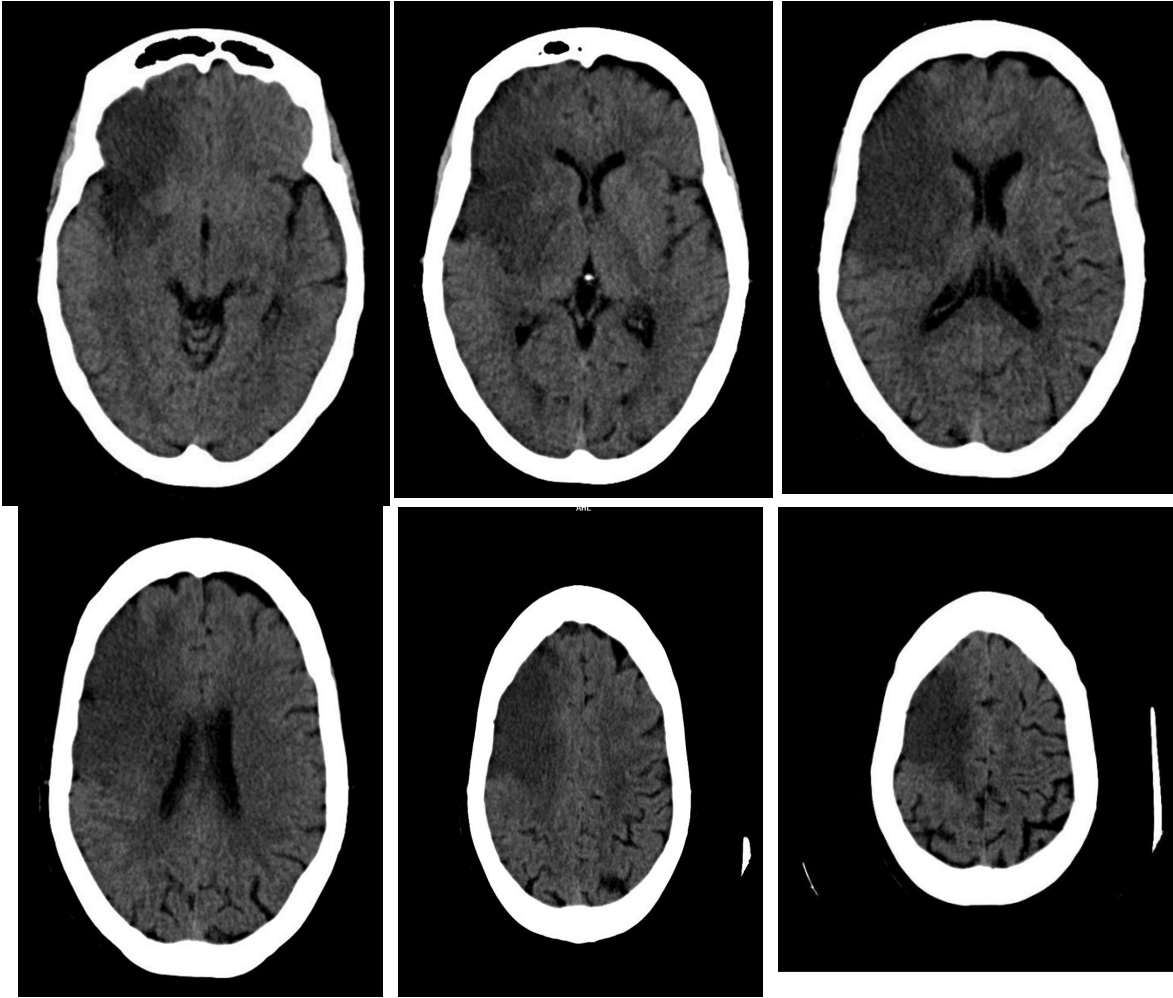
Case (2): 65Y old Female Unconscious CT image shows right side
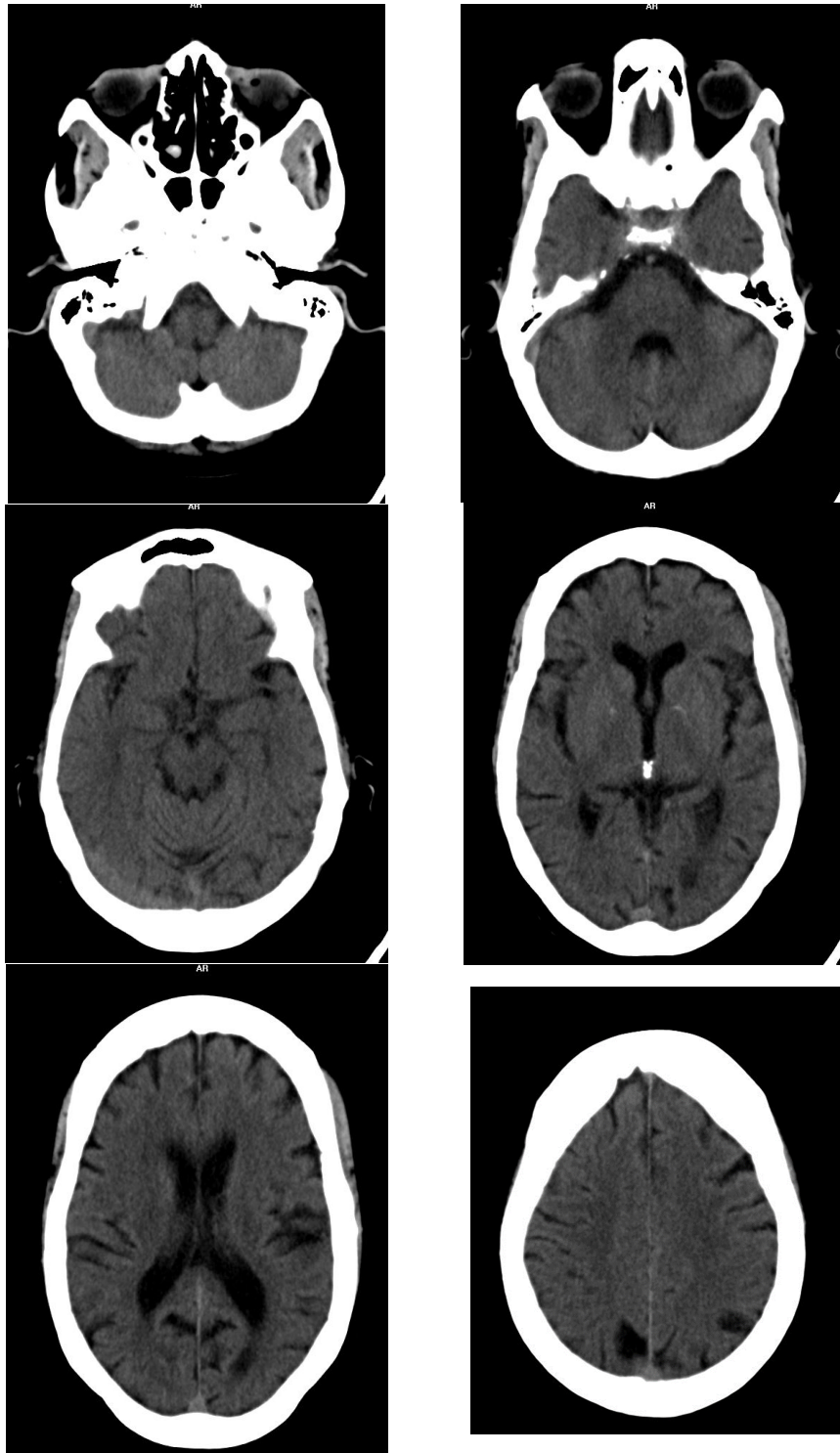frontoparietal acute infarction
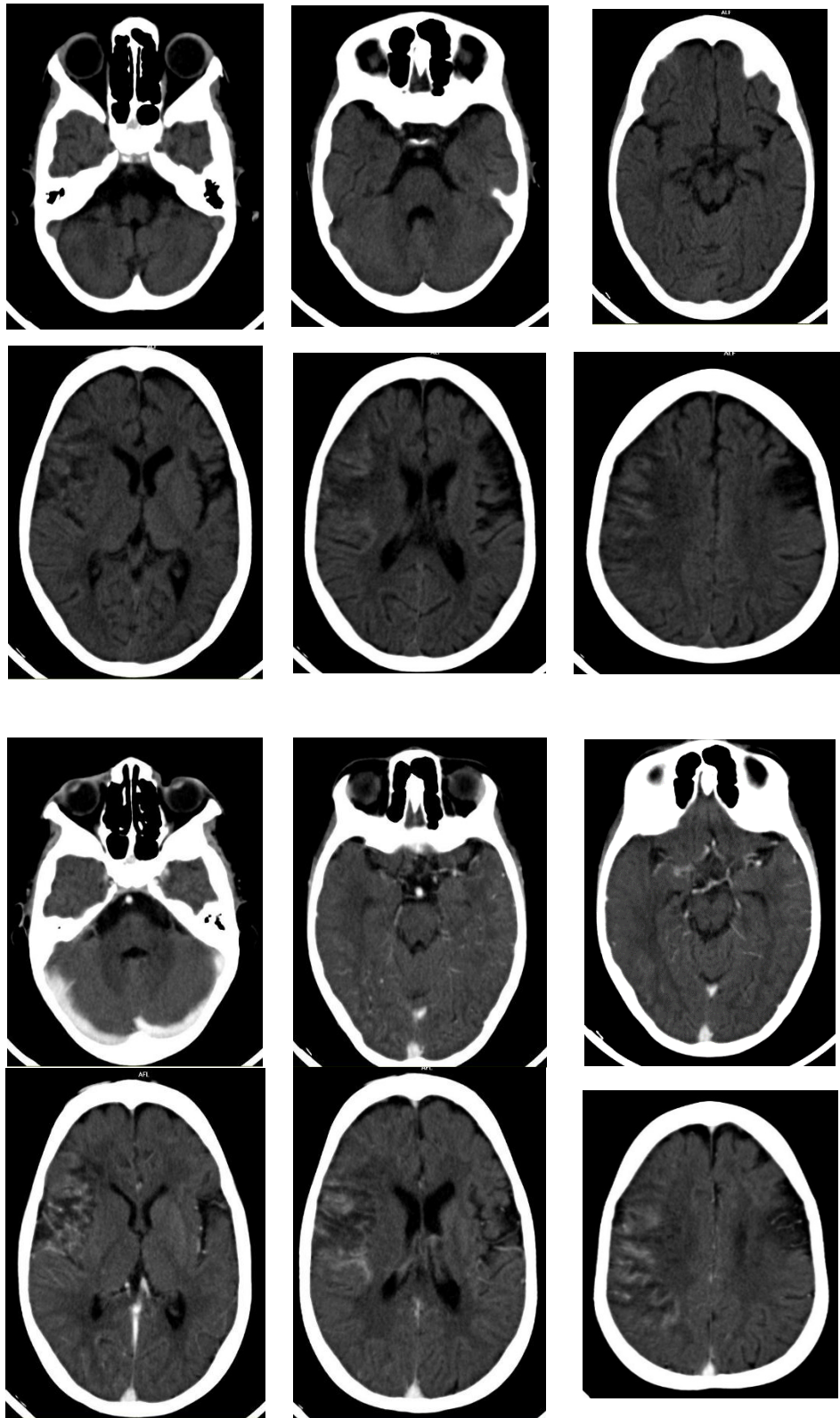
Case (3): 6Y old Male with Convulsions CT image shows right side temporal encephalitis
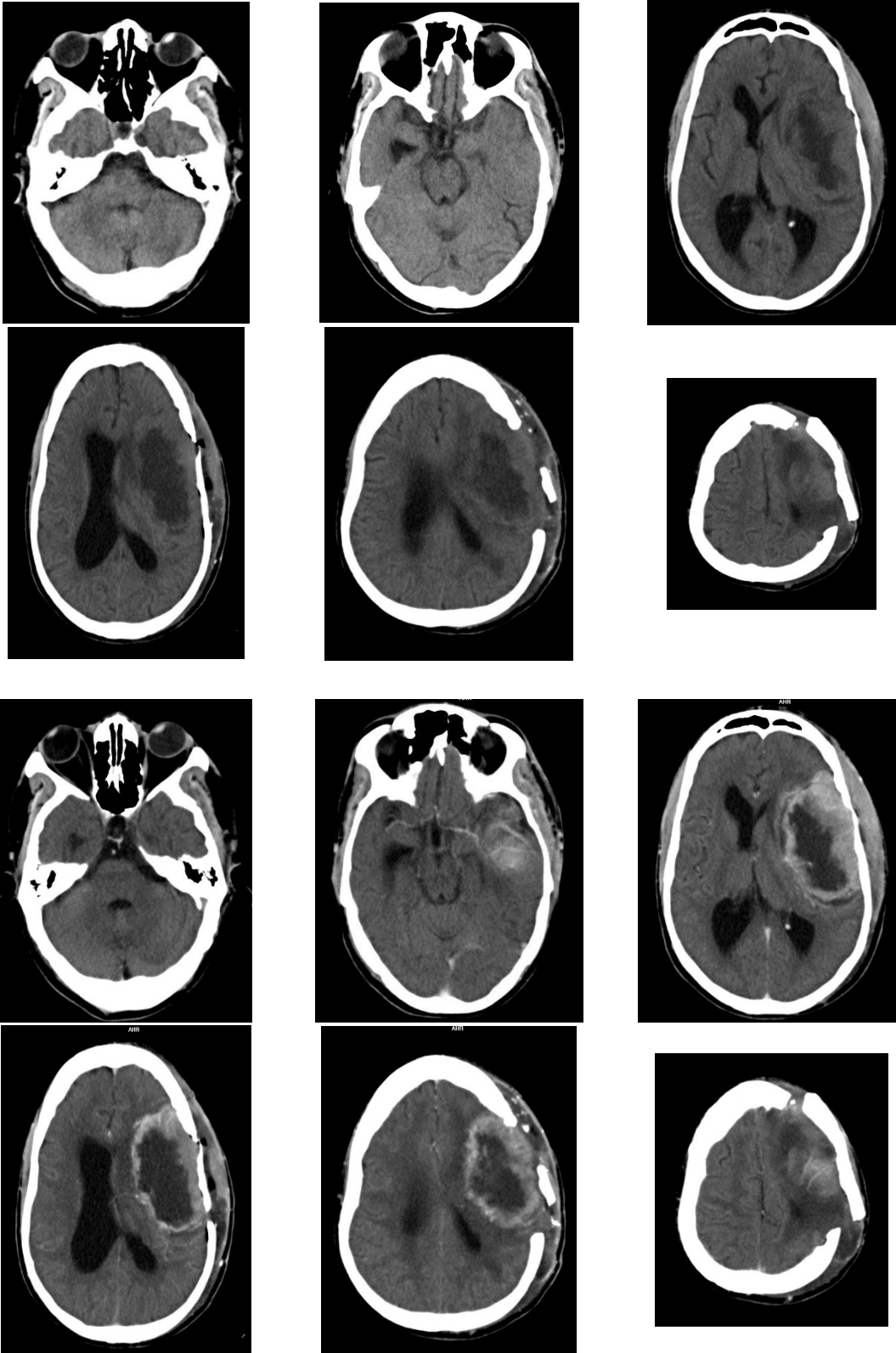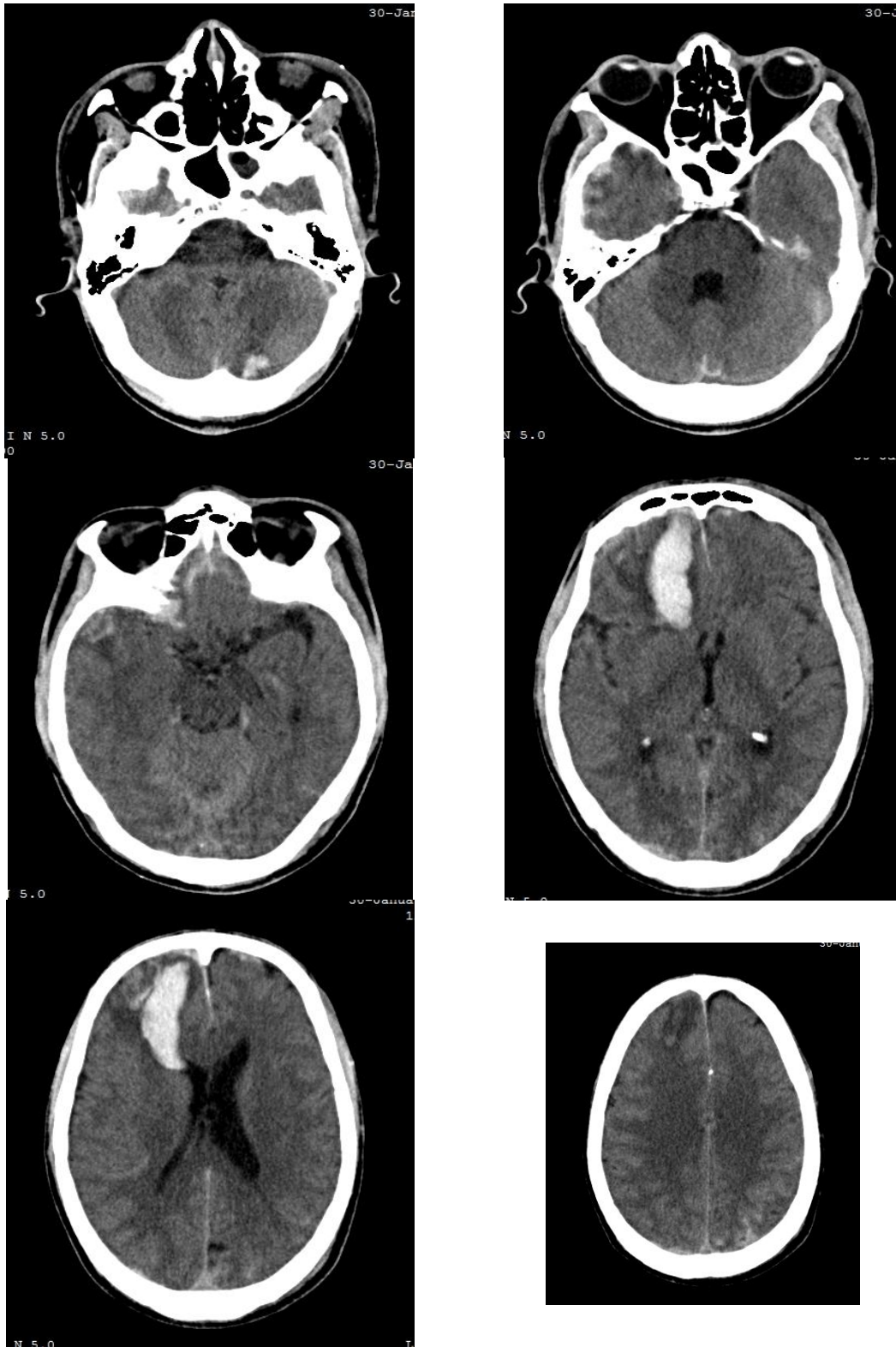
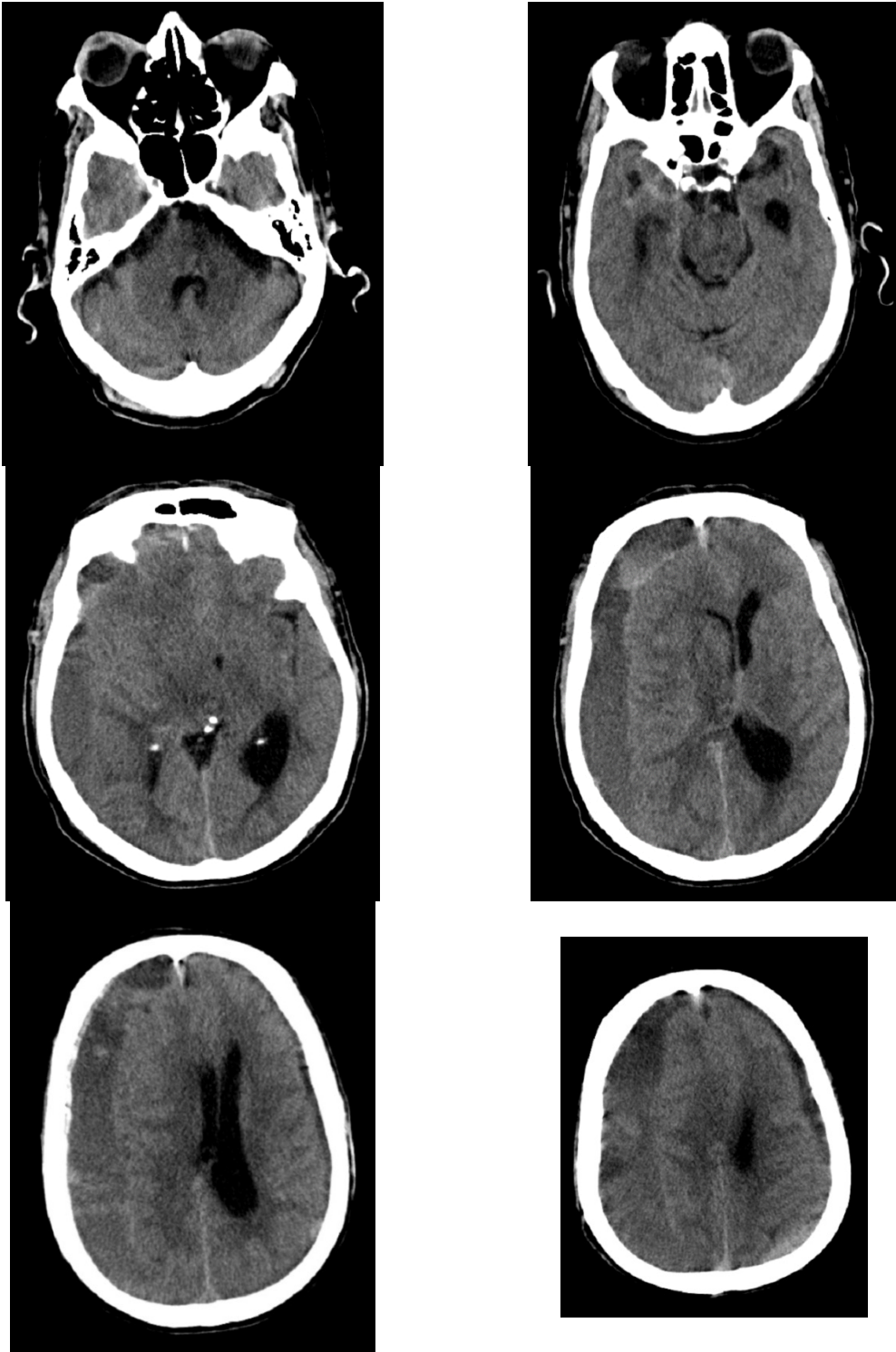Case (4): 25Y old Male with Chronic headache CT image shows left side Glioblastoma.

Case (5): 50Y old Male with Trauma CT image shows left side epidural hematoma and cerebral contusion.

Case (6): 55Y old Female with Dizziness CT image shows left side old infarction
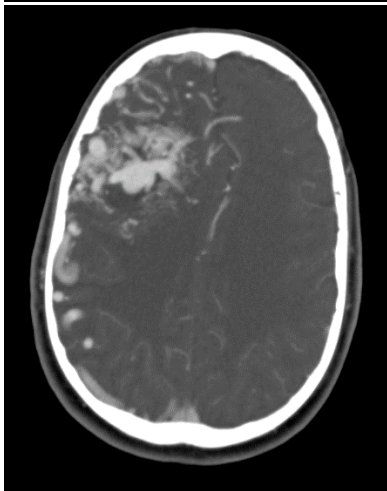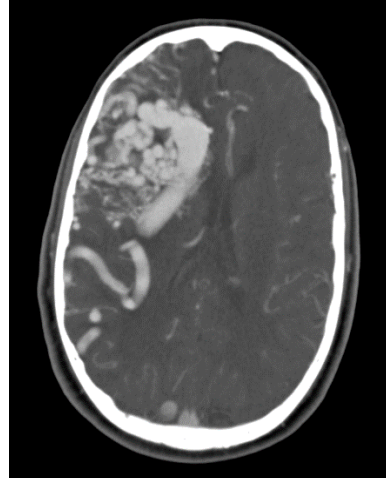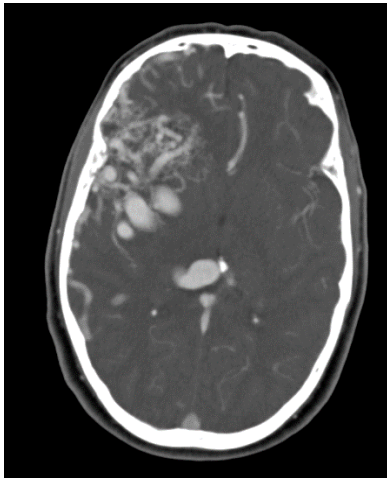
Case (7): 48Y old Female with headache CT image shows right side acute intra cerebral hematoma.

Case (8): 48Y old Female with headache CT image shows right side
subacute subdural hematoma
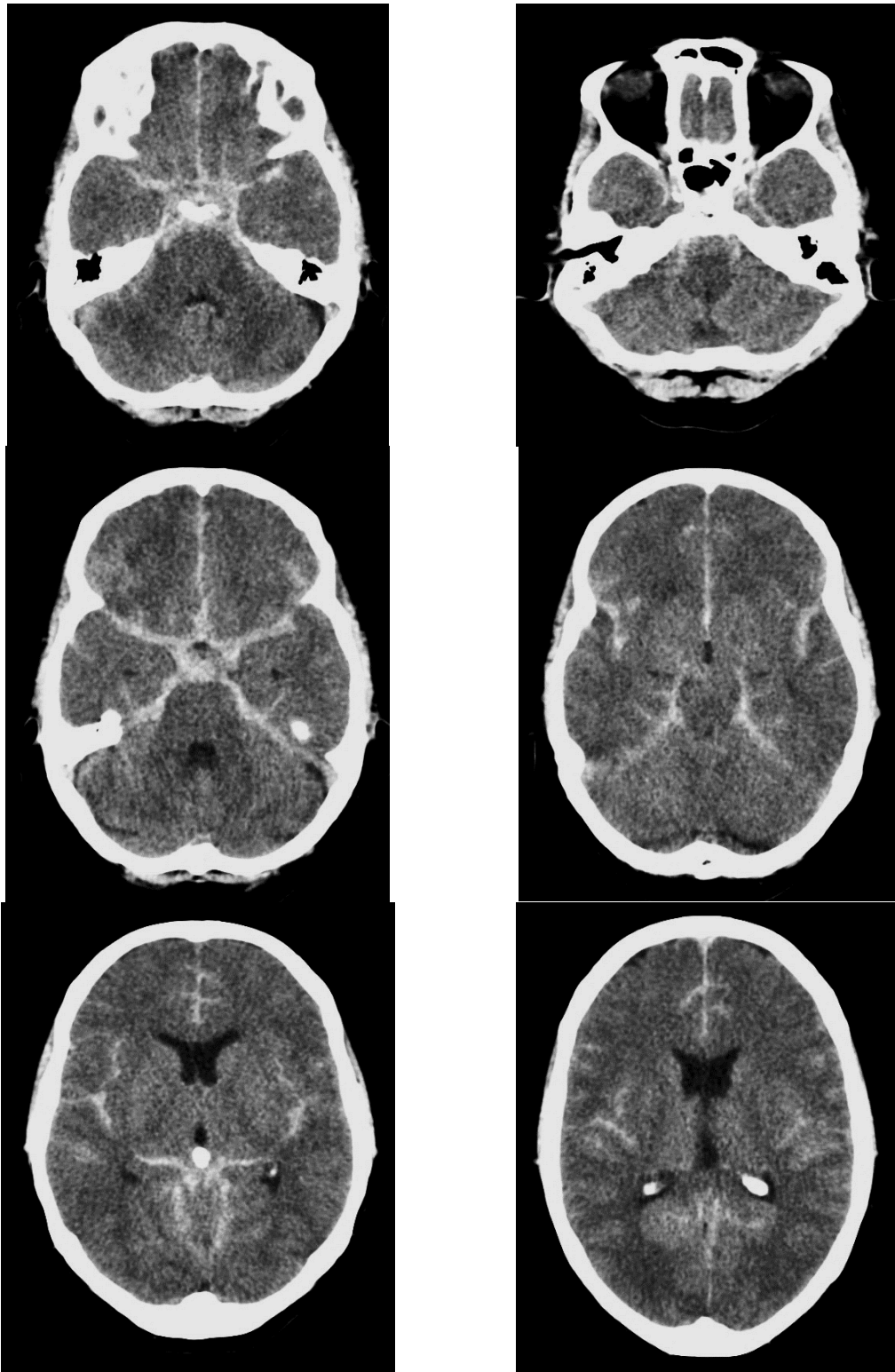
Case (9): 80Y old Female with Deterioration of neurological status CT
image shows acute subarachnoid hematoma
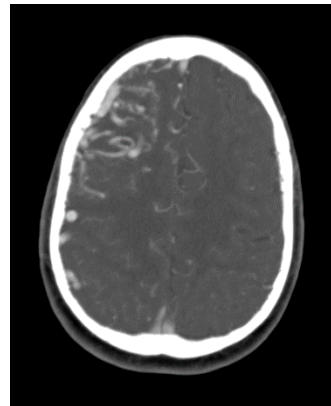
Case (10): 80Y old Male with Headache CT image shows right side huge
AVM

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. None ☐