Sudan University of Science and Technology

College of Graduate Studies

Estimation of Pediatric Dose during Computed Tomography of the Brain

تحديد الجرعة الإشعاعية للأطفال في تصوير المخ باستخدام الأشعة المقطعية

A thesis Submitted For Partial Fulfillment of The Requirements of M.S.C In Diagnostic Radiological technology

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الايـة

بسم الله الرحمن الرحيم

قال تعالي :

{هُوَ الَّذِي يُصَوِّرُكُمْ فِي الأَرْحَامِ كَيْفَ يَشَاءُ لاَ إِلَـهَ إِلاَّ هُوَ الْعَزِيزُ الْحَكِيمُ }

صدق الله العظيم

(آل عمران:6)

Dedication

This thesis dedicated to the rest of my family-my wonderful parents, brother, in-laws nieces, and nephews. To me brilliant colleagues, fellows, and residents.

Acknowledgments

First I would like to thanks God for the opportunity to be involved in this project, the wisdom to undertake it, and the determination to see it through.

I would like to express my sincere thanks to all my colleagues who have provided suggestion and contribution. My gratitude is extended to my supervisor Dr. Asmaa for her helps.

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List of abbreviations

CT	Computed Tomography
2D image	Two Dimensional Image
MSCT	Multi-Slice Computed Tomography
SSCT	Single-Slice Computed Tomography
DRL	Diagnostic Reference Level
CSF	Cerebrospinal Fluid
CNS	Central Nervous System
mSV	milli-Sivert
LNT	linear non-threshold
ED	Emergency Department
CTDI	Computed Tomography Dose Index
DLP	Dose Length Product
mG	Ymilli-gray
kV	killo-volt
MA	mili-ampar
US	united state
UK	United Kindom
MAs	milli-ampar second
ECE	uropean Commission
CTDI	volComputed Tomography Index Volume
KV	pkillo-volt peak
mG	Y-cmmilli-gray centemeter
SPSS	Statistical Packages for Social Scinecs
STD	Stander deviation
No of Pts	Number ofpatients
DSH	Dar Al Elaj Specialized Hospital
RCIH	Royal Care International Hospital

Abstract

This study was descriptive and analytic study aim to estimate radiation dose to pediatric patients during Computed Tomography (CT) Examinations in three hospital in Khartoum state Dar Elaj specialized hospital, Royal Care International hospital and East Nile hospitals in period from April 2016 to May 2017 and the results show that themilli-ampar second (mAs) values was higher in Dar Elaj Specialized hospital (372.28) than other hospitals (202.6 and 147.18), and in case ofkillo-volt peak(KVp),computed tomography dose index volume (CTDIvol), dose length product (DLP) and effective dose was higher in Royal care 120,47.70,1307,27 and 24.44 then Dar Elaj 115.71, 45.46,1082.72 and 20.23 then East Nile 115.62, 43.01, 869.13 and 16.25.

In correlation ofmilli-ampar second(mAs) with other variables found that the relation of milli-ampar second (mAs) with dose length product (DLP) (0.06) and effective dose (0.064) was week relation, and milli-ampar second (mAs) with computed tomography dose index volume (CTDIvol) (0.31) was moderate.

And the correlation the effective dose (ED) with computed tomography index volume (CTDIvol) (0.34) show that there is moderate relation between them.

The main dose variations in the same computed tomography (CT) unit could be attributed to the different techniques, which justify the important of use radiation dose optimization technique and technologists training. Dose reduction strategies must be well understood and properly used.

المستخلص

الهدف من هذه الدراسة لتقييم الجرعة الاشعاعية للأطفال في اختبارات الأشعة المقطعية في ثلاثة مستشفيات بولاية الخرطوم (مستشفي دار العلاج، مستشفي رويال كير و مستشفي شرق النيل) في الفترة من ابريل 2016 الي مايو 2017 و كانت النتائج المتحصل عليها كالآتي:

أعلي نتائج للملي أمبير كانت في مستشفي دار العلاج (372.28) و من ثممستشفي رويال كير(202.6) يليها مستشفي شرق النيل (147.18).

و بالنسبة لقيمة الكيلوفولت و طول الجرعة الناتجة وجرعة الأشعة المقطعية الحجمية و الجرعة الفعالةكانت أعلي في مستشفي رويال كير يليها دار العلاج و أخيرا بمستشفي شرق النيل.

و كانت نتائج العلاقة بين ملي أمبير مع طول الجرعة الناتجةوالجرعة الفعالة كانت علاقة ضعيفة ، والعلاقة بين الملي أمبير مع جرعة الأشعة المقطعية الحجمية كانت متوسطة.

والعلاقة ببين الجرعة الفعالة وجرعة الأشعة المقطعية الحجمية كانت علاقة متوسطة.

و كانت قيم الجرعة الاشعاعية مختلفة بين جميع المستشفيات لاختلاف طريقة التصوير من مستشفي لآخر، والتي تبرر بعدم الاستخدام الأمثل لاجهزة الأشعة المقطعية و يجب علي التقنيين التعامل معها باعتبارها ذات تاثير اشعاعي كبير وتاثير بايولوجي عالي خصوصا عند الأطفال.

Chapter One

Introduction

Chapter One

1.1 Introduction:

Computed tomography (CT) is an imaging technique which produces a digital topographic image from diagnostic x-ray. In the early 1970s a major innovation was introduced into diagnostic imaging. This innovation, x-ray computed tomography (CT), is recognized today as the most significant single event in medical imaging since the discovery of x-rays (William R., E. Russell, 2002).

Computed Tomography (CT) was invented by a British engineer, Sir Godfrey Hounsfield who also won the Nobel Prize because of Jhis invention. CT was first introduced in the clinical practice in 1972 which was only limited to the brain scan. Prior to that, X-ray planar radiography and fluoroscopy systems were the main contributors of radiation in imaging (Goldman 2007).

Computed tomography (CT) is in its fourth decade of clinical use and has proved invaluable as a diagnostic tool for many clinical applications, from cancer diagnosis to trauma to osteoporosis screening. CT was the first imaging modality that made it possible to probe the inner depths of the body, slice by slice. Since 1972, when the first head CT scanner was introduced, CT has matured greatly and gained technological sophistication. Concomitant changes have occurred in the quality of CT images. The first CT scanner, an EMI Mark 1, produced images with 80 X 80 pixel resolution (3-mm pixels), and each pair of slices required approximately 4.5 minutes of scan time and 1.5 minutes of reconstruction time. Because of the long acquisition times required for the early scanners and the constraints of cardiac and respiratory motion, it was originally thought that CT would be practical only for head scans.

In its most basic form, a rotating X-ray beam emits ionizing radiation of a defined thickness, which is used to irradiate the patient from numerous

projections. Detectors located on the other side of the patient, opposite the source of the beam, register the amount of radiation that has penetrated through the patient. By calculating these values for numerous projections, a two dimensional image of a specified thickness is generated (keith et al 2010).

These images possess contrast resolution that is far superior to conventional radiography, demonstrating the ability to distinguish substances of only slightly different densities.

Once such a 2-D image is acquired, the patient is advanced through the CT gantry for a predefined distance, and then the process is repeated This is known as “step-and-shoot” technology.

Over the 20 years following its introduction, significant improvements,In this technology were made. These advances were largely the result of improvements in X-ray beam emission and detector technology, matched by advances in computer technologies to facilitate the data processing of high level functions (Anne Paterson 2001).

1.2 Problem of study

Most clinics in Sudan do not apply diagnostic reference level, use same exposure factor to pediatric as same as to Adults patients without using base line of practice. And provides the different values of doses from different modalities in CT machines .

1.3 Objectives of Study :

1.3.1 General objective:

- The aim of the study is to estimate radiation dose to Pediatric patients during brain Computed Tomography Examinations.

1.4.2 Specific objective:

- To estimate the dose length product (DLP).
- Propose a local diagnostic reference level (DRL).
- To Compare between CT scan dose at various Diagnostic Centers.
- Estimate the pediatric patient effective dose for the brain.

1.5 Research Overview

Chapter one is the introduction to this thesis. This chapter discusses the objectives and scope of work and introduces necessary background. It also provides an outline of the thesis.

Chapter two contains the background material for the thesis. Specifically it discusses the dose for all absorbed dose measurements and calculations. This chapter also includes a summary of previous work performed in this field and reviewed different dosimetric techniques used in patient dose measurements.

Chapter three describes the materials and a method used to measure dose for routine radiography machines and explains in details the methods used for dose calculation.

Chapter four presents the results of this study.

Chapter five presents the discussion, conclusion and recommendations of the thesis.

Chapter Two

Theoretical Background

Chapter Two

Theoretical Background

2.1 Anatomy of the brain:

2.1.1 Cerebrum

The largest part of the human brain is the cerebrum, which consists of two hemispheres separated by the longitudinal fissure. At the base of this deep groove is the corpus callosum, a band of 200 million neurons that connects the right and left hemispheres. Within each hemisphere is a lateral ventricle (Scanlon 2007).

The surface of the cerebrum is gray matter called the cerebral cortex. Gray matter consists of cell bodies of neurons, which carry out the many functions of the cerebrum. Internal to the gray matter is white matter, made of myelinated axons and dendrites that connect the lobes of the cerebrum to one another and to all other parts of the brain in the human brain the cerebral cortex is folded extensively. The folds are called convolutions or gyri and the grooves between them are fissures or sulci this folding permits the presence of millions more neurons in the cerebral cortex. The cerebral cortex is divided into lobes that have the same names as the cranial bones external to them. Therefore, each hemisphere has a frontal lobe, parietal lobe, temporal lobe, and occipital lobe,(Scanlon 2007).

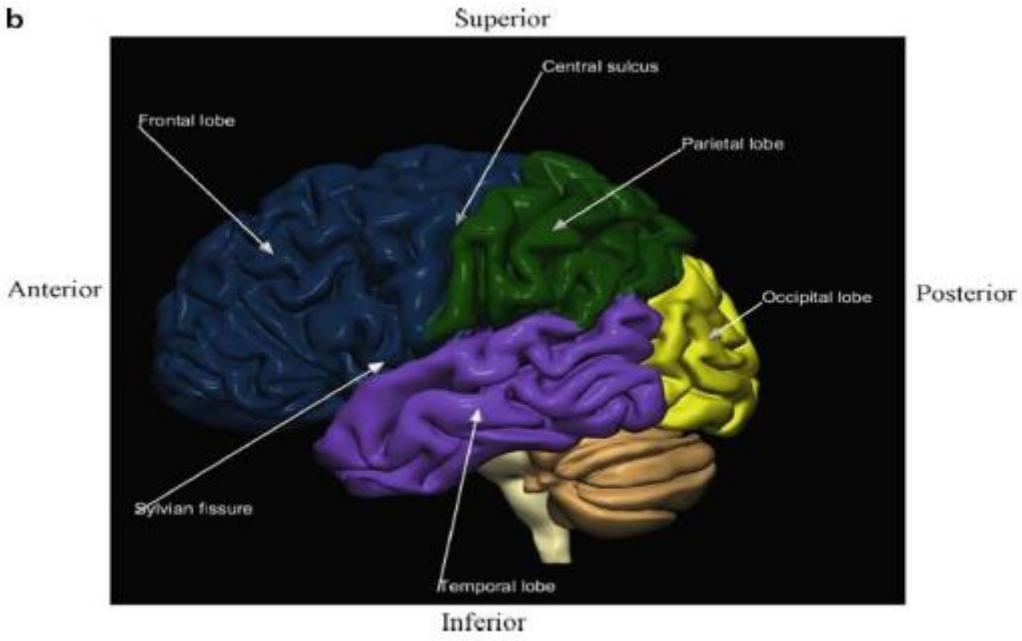

Fig (2.1) shows the brain lobes **(**Nowinski 2011)

2.1.2 Frontal lobes

On its lateral aspect, the frontal lobe extends from the frontal pole to the central sulcus, constituting the anterior one-third of the cerebral cortex. Its posteriormostgyrus, the precentralgyrus, consists of the primary motor area and is bordered anteriorly by the precentral sulcus and posteriorly by the central sulcus. The region of the frontal lobe located anterior to the precentral sulcus is subdivided into the superior, middle, and inferior frontal gyri. This subdivision is due to the presence, though inconsistent, of two longitudinally disposed sulci, the superior and inferior frontal sulci. The inferior frontal gyrus is demarcated by extensions of the lateral fissure into three subregions: the pars triangularis, pars opercularis, and pars orbitalis. In the dominant hemisphere, a region of the inferior frontal gyrus is known as Broca‘s area, which functions in the production of speech. On its inferior aspect, the frontal lobe presents the longitudinally disposed olfactory sulcus. Medial to this sulcus is the gyrus rectus (also known as the straight gyrus), and lateral to it are the orbital gyri. The olfactory sulcus is partly occupied by the olfactory bulb and olfactory tract its posterior extent, the olfactory

tract bifurcates to form the lateral and medial olfactory striae. The intervening area between the two striae is triangular in shape and is known as the olfactory trigone and it abuts the anterior perforated substance. On its medial aspect, the frontal lobe is bordered by the arched cingulate sulcus, which forms the boundary of the superior aspect of the cingulate gyrus. The quadrangular-shaped cortical tissue anterior to the central sulcus is a continuation of the precentralgyrus and is known as the anteriorparacentral lobule (Maria2006)

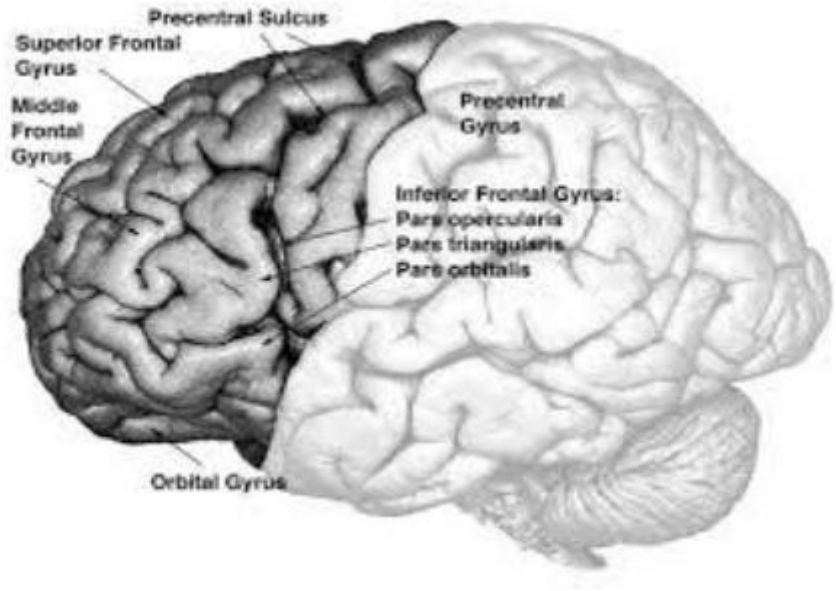

Fig (2.2) anatomy of the frontal lobe (Maria2006)

2.2 Parietal Lobes

The parietal lobe is interposed between the frontal and occipital lobes and is situated above the temporal lobe. On its lateral aspect, its anterior most gyrus, the post central gyrus, is the primary somesthetic area to which primary somatosensory information is channeled from the contra lateral half of the body (Scanlon 2007).

The remainder of the parietal lobe, separated from the post central gyrus by the post central sulcus, is subdivided by the inconsistent intraparietal sulcus, into the superior and inferior parietal lobules. The former is an association area involved in somatosensory function, whereas the latter is separated into

the supramarginalgyrus, which integrates auditory, visual, and somatosensory information, and the angular gyrus on its medial aspect, the parietal lobe is separated from the occipital lobe by the parieto-occipital sulcus and its inferior continuation, the calcarine fissure. This region of the parietal lobe is subdivided into two major structures, the interiorly positioned posterior par central lobule and the posteriorly situated precuneus (Rehani 2000).

2.2.1 Temporal Lobe:

The temporal lobe is separated from the frontal and parietal lobes by the lateral fissure and from the occipital lobe by an imaginary plane that passes through the parieto-occipital sulcus. The anteriormost aspect of the temporal lobe is known as the temporal pole. On its lateral aspect, the temporal lobe exhibits three parallel gyri, the superior, middle, and inferior temporal gyri, separated from each other by the inconsistently present superior and middle temporal sulci. The superior temporal gyrus of the dominant hemisphere contains Wernicke‘s area, The inferior aspect of the temporal lobe is grooved by the inferior temporal sulcus that is interposed between the inferior temporal gyrus and the lateral occipitotemporalgyrus (fusiform gyrus). The collateral sulcus separates the fusiform gyrus from the parahippocampalgyrus of the limbic lobe (Maria 2006).

2.1.1.4 Occipital Lobe:

The occipital lobe extends from the occipital pole to the parieto-occipital sulcus.On its lateral aspect, the occipital lobe presents the superior and inferior occipital gyri, separated from each other by the horizontally running lateral occipital sulcus. On its medial aspect, the occipital lobe is subdivided into the superiorly located cuneategyrus (cuneus) and the inferiorly positioned lingual gyrus, separated from each other by the calcarine fissure. The cortical tissue on each bank of this fissure is known collectively as the striate cortex (calcarine cortex), and forms the primary (Rehani 2000).

2.2.3 visual cortex:

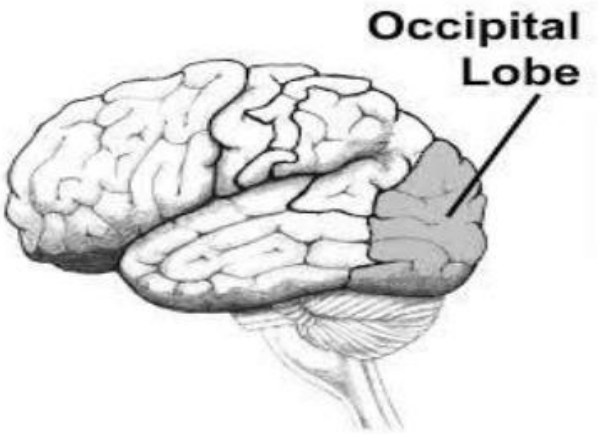

Fig (2.3) demonstrate the occipital lobe (Rehani 2000).

2.2.4 Limbic lobe:

The limbic lobe is a complex region and includes the cingulate gyrus, parahippocampalgyrus, hippocampal formation, subcallosalgyrus, parolfactorygyrus, and the preterminalgyrus. The following description is a view of the medial aspect of the hemisected brain and the various regions of the corpus callosum are obvious landmarks. Therefore, the corpus callosum will now be described, even though it is not a part of the limbic lobe. The anterior extent of the corpus callosum, known as the genu, bends inferiorly and turns posteriorly, where it forms a slender connection, the rostrum, with the anterior commissure.

The posterior extent of the corpus callosum is bulbous in shape, and is known as the splenium the cingulate gyrus is located above the corpus callosum and is separated from it by the callossal sulcus. As the cingulate gyrus continues posteriorly, it follows the curvature of the corpus callosum and dips beneath the splenium to continue anteriorly as the isthmus of the cingulate gyrus. The anterior continuation of the isthmus is the parahippocampalgyruswhoseanteriormost extent is known as the uncus(Rehani 2000).

Above the parahippocampalgyrus is the hippocampal sulcus, which separates the parahippocampalgyrus from the hippocampal formation (composed of the hippocampus, subiculum, and dentate gyrus). Just beneath the rostrum of the corpus callosum is the subcallosalgyrus. The connection between the anterior commissure and the optic chiasma is the lamina terminalis and the cortical tissue anterior to the lamina terminalis is the parolfactorygyrus and preterminalgyrus, Thesubcallosal, parolfactory, and preterminalgyri are referred to as the subcallosal area (Maria 2006).

2.3 Ventricles

The ventricles are four cavities within the brain: two lateral ventricles, the third ventricle, and the fourth ventricle each ventricle contains a capillary network called a choroid plexus, which forms cerebrospinalfluid (CSF) from blood plasma. Cerebrospinal fluid is the tissue fluid of the central nervous system(Rehani 2000).

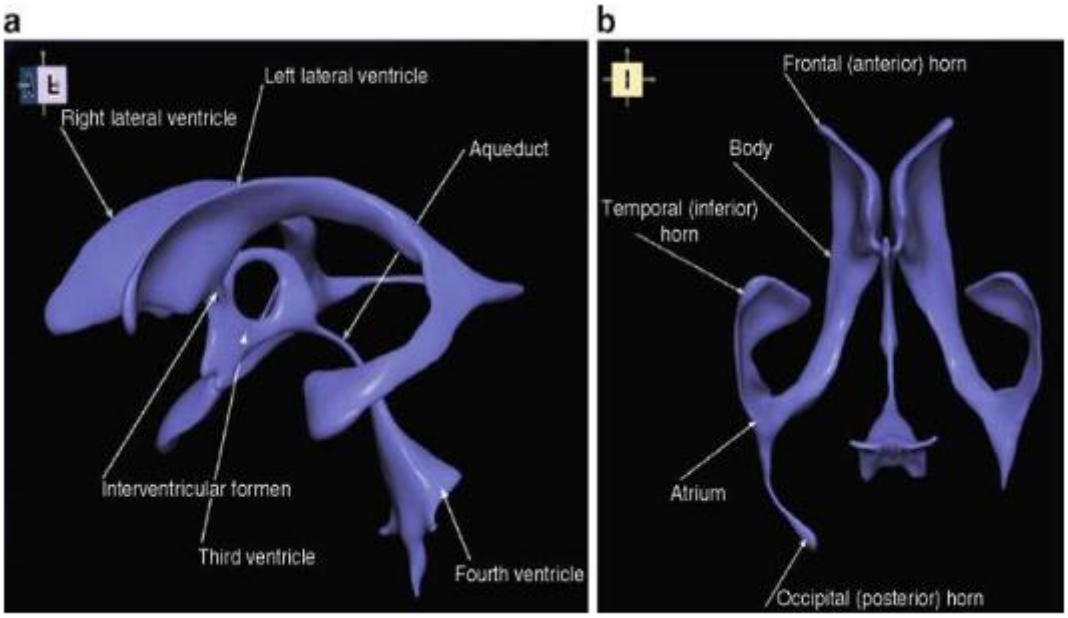

Fig (2.4) shows the ventricular system (Nowinski 2011)

2.4 Cerebellum

The cerebellum is located in the posterior aspect of the brain, just below the occipital lobes of the cerebrum. It is separated from the cerebrum via a horizontal dural reflection, the tentorium cerebelli. The cerebellum is

connected to the midbrain, pons, and medulla of the brainstem via three pairs of fiber bundles, the superior, middle, and inferior cerebellar peduncles, respectively.

Viewing the cerebellum, it can be seen that it is composed of the right and left cerebellar hemispheres and the narrow, intervening vermis. The vermis is also subdivided into a superior and an inferior portion, where the superior portion is visible between the two hemispheres, while its inferior portion is buried between the two hemispheres. The surface of the cerebellum has horizontal elevations, known as folia, and indentations between the folia, known as sulci. Some of these sulci are deeper than others and they are said to subdivide each hemisphere into three lobes, the small anterior lobe, the much larger posterior lobe, and the inferiorly positioned flocculonodular lobe (formed from the nodule of the vermis and the flocculus of each cerebellar hemisphere). The anterior lobe is separated from the posterior lobe by the primary fissure, and the posterolateral fissure separates the flocculonodular lobe from the posterior lobe. Similar to the cerebrum, the cerebellum has an outer rim of gray matter, the cortex, an inner core of nerve fibers, the medullary white matter, and the deep cerebellar nuclei, located within the white matter. The cortex and white matter are easily distinguished from each other in a midsagittal section of the cerebellum, where the white matter arborizes, forming the core of what appears to be a tree-like architecture, known as the arbor vitae. Histologically, the cerebellar cortex is a three-layered structure, the outermost molecular layer, the middle Purkinje layer, and the innermost granular layer. The granular layer is well defined due to the presence of nucleic acids in the nuclei of its numerous, small cells. The Purkinje layer, composed of a single layer of large Purkinje cell perikaryons, is also easily recognizable. The molecular layer is rich in axons and dendrites as well as capillaries that penetrate deep into this layer. Four pairs of nuclei are located within the substance of the cerebellar white

matter. These are the fastigial, dentate, emboliform, and globose nuclei. The connections between the cortical regions and the deep nuclei of the cerebellum permit the subdivision of the cerebellum into three zones— the vermal, paravermal, and hemispheric—where each zone is composed of deep cerebellar nuclei, white matter, and cortex. (Maria et al 2006)

2.4.1The brain stem:

The brain stem is composed of medulla, pons and midbrain

2.4.2 Medulla:

The medullaextends from the spinal cord to the pons and is anterior to the cerebellum.

2.4.3 Pons:

The Ponsbulges anteriorly from the upper part of the medulla. Within the pons are two respiratory centers that work with those in the medulla to produce a normal breathing rhythm.The many other neurons in the pons (ponsis from the Latin for ―bridge‖) connect the medulla with other parts of the brain.

2.4.4 Mid brain:

The midbrain extends from the pons to the hypothalamus and encloses the cerebral aqueduct, a tunnel that connects the third and fourth ventricles. (Scanlon 2007)

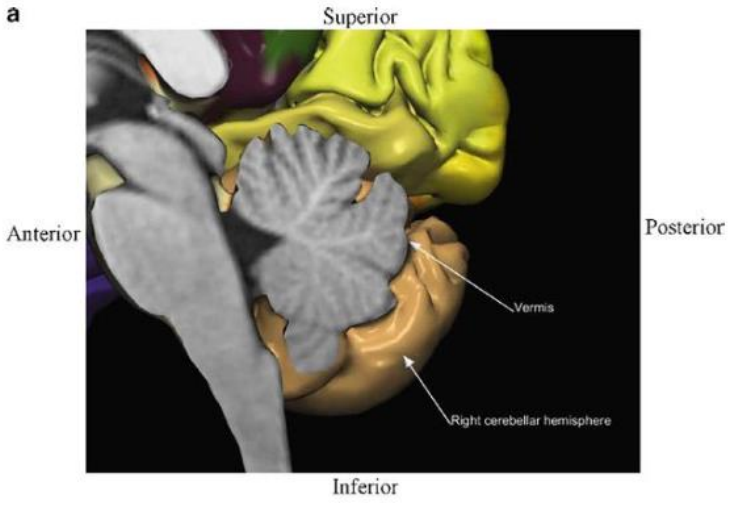

Fig (2.5) show midbrain extends from the pons(Scanlon 2007)

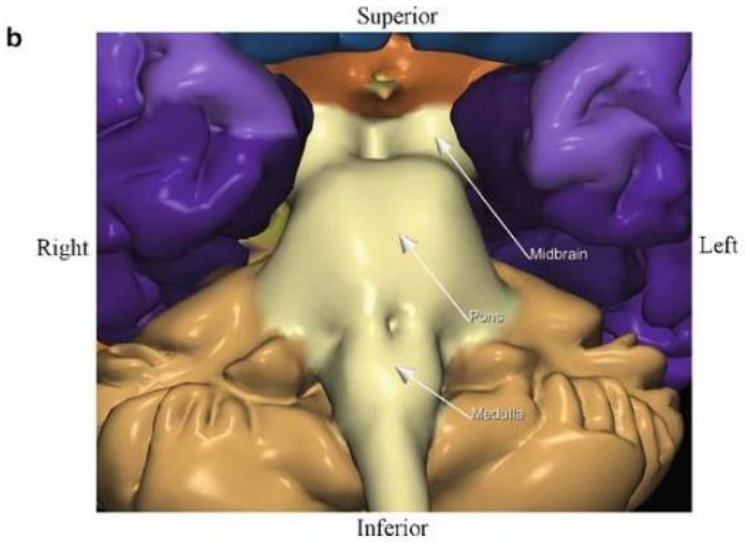

Fig (2.6) cerebellum and brain stem (Wieslaw L. et al2011)

2.5 Hypothalamus

Located superior to the pituitary gland and inferior to the thalamus, the hypothalamus is a small area of the brain with many diverse functions

2.5.1 Thalamus

The thalamusis superior to the hypothalamus and inferior to the cerebrum. The third ventricle is a narrow cavity that passes through both the thalamus and hypothalamus (Rehani 2000).

2.5.2 Basal Ganglia

The basal ganglia, called ganglia even though they are nuclei, are large collections of cell bodies that are embedded deep in the white matter of the brain These soma include those deep nuclei of the brain and brainstem which, when damaged, produce movement disorders. Thus the basal ganglia are composed of the caudate nucleus, lenticular nucleus (putamen and globuspallidus), subthalamic nucleus of the ventral thalamus, and the substantianigra of the mesencephalon (the caudate nucleus and the putamen together are referred to as the striatum). These nuclei have numerous connections with various regions of the CNS; some receive input and are categorized as input nuclei, some project to other regions and are referred to as output nuclei, whereas some receive input, project to other regions of the

CNS, and have local interconnections and these are known as intrinsic nuclei (Maria et al 2006)

2.6 Physiology of the brain:

The brain is found in the cranial cavity. Within it are found the higher nerve centers responsible for coordinating the sensory and motor systems of the body. The brain stem houses the lower nerve centers (consisting of midbrain, pons, and medulla).

2.6.1 Cerebrum:

The cerebrum, or top portion of the brain, is divided by a deep crevice, called the longitudinal sulcus. The longitudinal sulcus separates the cerebrum in to the right and left hemispheres. In the hemispheres you will find the cerebral cortex, basal ganglia and the limbic system. The two hemispheres are connected by a bundle of nerve fibers called the corpus callosum. The right hemisphere is responsible for the left side of the body while the opposite is true of the left hemisphere. Each of the two hemispheres are divided into four separated lobes:

the frontal in control of specialized motor control, learning, planning and speech; parietal in control of somatic sensory functions; occipital in control of vision; and temporal lobes which consists of hearing centers and some speech.Located deep to the temporal lobe of the cerebrum is the insula. (Wiki books contributors 2007).

2.6.2 Cerebellum:

The cerebellum is the part of the brain that is located posterior to the medulla oblongata and pons. It coordinates skeletal muscles to produce smooth, graceful motions. The cerebellum receives information from our eyes, ears, muscles, and joints about what position our body is currently in. It also receives output from the cerebral cortex about where these parts should be. After processing thisinformation, the cerebellum sends motor impulses from the brainstem to the skeletal muscles. The main function of the cerebellum is

coordination. The cerebellum is also responsible for balance and posture. It also assists us when we are learning a new motor skill, such as playing a sport or musical instrument (Goldman et al 2007).

2.7 Pathology of the brain:

2.7.1 Neurodegenerative disorders:

Neurodegenerative disorders must be distinguished from normal aging. The neurodegenerative disorders are characterized by loss of functionally related groups of neurons anatomically. Clinical manifestations reflect the functional oss which can be correlated anatomically in many situations. The following is a brief correlation of symptoms to lots of specific neuronal populations:

Cortical neurons: dementia, basal ganglia neurons, cerebellar neurons and motor neurons: Weakness. The etiology is not clear but current attention has been paid to chronic cellular injury, neurotoxin, stress at the cellular level, and cellular injury from excitoxicity, damage due to free radicals. some of the neurodegenerative are genetically transmitted. Expansion of trinucleotide repeats in the gene involved is identified in these disordersThree major function of the CNScognition and affect, motor, autonomic function. Clinically, neurodegenerative diseases usually manifest as disturbance of one of these three functions or in combinations as their chief manifestation (Goldman et al 2007).

Examples are as follows:

Alzheimer‘s disease, frontotemporal dementia: language skill and frontal lobe symptoms, Parkinson‘s disease, amyotrophic lateral sclerosis, diffuse Lewy body disease: Motor and cognition and multiple system atrophy: Autonomic dysfunction (including orthostgatichyoptention, impotance) and other dysfunctions such as Parkinsonism. (Kar-Ming Fung 2006)

2.7.2 Demyelinating disease:

Incidence: Demyelinating diseases, particularly multiple sclerosis, are common. Demyelination is loss of normal myelin that has already been formed. And dysmyelination is Failure to form normal myelin or maintain normal myelination as in leuko dystrophies.

2.8 Classifications:

2.8.1 Primary Demyelinating diseases:

Multiple sclerosis and inflammatory demyelinating pseudotumor

2.8.2 Secondary Demyelinating diseases:

Central pontinemyelinolysis and Acute disseminated perivousencephalomyelitis (acute perivascular myelinoclasis), Classic (parainfectious-postimmunization idiopathic), Hyperacute (acute hemorrhagic leukoencephalitis) and Progressive multifocal leukodystrophy.

2.8.3 Multiple Sclerosis (MS):

Characteristic: A chronic, often relapsing, demyelinatingdisease with onset most commonly seen in young adults.The mean age of onset is 30 year-old; unusual to have onset in children under 10 year-old.More common in females, male to female ratio is 1:2 in adults, 1:10 in children (Goldman et al 2007).

2.9 Clinical features:

Chronic relapsing disease.About 10% of the patients continue to progress without remission. Optic neuritis and double vision are very often.Severity of clinical manifestation may not reflect the extent of pathologic change.

2.9.1 Neuroimaging:

MRI is the most sensitive method of detection.Preiventricular white matter adjacent to the body and the trigones of the lateral ventricle.The plaques are often ovoid and with long axis parallel to the ventricles Enhancement is seen in acute plaques but not chronic plaque (Goldman et al 2007).

2.9.2 Gross pathology:

Plaque: Almond to oval lesions that range from a few mm to a few cm. Periventricular, optic nerve, spinal cord as most common locations.Affect predominantly the white matter.

2.9.3 Histology:

Affect predominantly the white matter.Often with multiple lesions at differentstages of evolution.Perivascular chronic inflammation with loss of myelin. Three stages**:** acute, subacute, chronic (burnt out) plaque. Reactive gliosis are more prominent in chronic plaques, inflammation is more prominent in acute plaques (Goldman et al 2007).

2.9.4 Gross Pathology:

Swelling and edema; the brain is otherwise free of macroscopic pathologic changes.

2.9.4.1 Histology:

Multifocal perivenous lymphocytic infiltration. Inflammatory cells extend into surrounding parenchyma. Demyelination with the blood vessels as the epicenters.

2.9.5 Acute Hemorrhagic Leukoencephalopathy

Characterized byThe most fulminant form of demyelinating disease and the patients usually die within days. The affected age mainly young adults, sometimes children.Clinical featuresare similar to ADEM but far more severe.Leukocytosis sometimes reaching 30,000 cells/mm3.Elevated erythrocyte sedimentation rate. CSF with polymorphonuclear leukocytosis, up to 3000 cells/mm3(Goldman et al 2007).

2.9.5.1 Gross Pathology:

The brain is swollen and soft, predominantly small but occasionally large hemorrhagic foci involving mostly the cerebrum and cerebellum and white matter in the pons.

2.9.5.2 Histology:

Mixed acute and chronic inflammatory cell infiltration.Rings and balls of hemorrhage: Blood vessels with fibrinoid necrosis rimmed by necrotic tissue and a larger zone of hemorrhage.Perivascular demyelination.

2.9.6 Central Pontine Myelinolysis

2.9.6.1 Characteristic:

A non-inflammatory, acute, demyelinating disease thattypically affects the pons and often associated with hyponatremia in alcoholics.

2.9.6.2 Gross Pathology:

Affects the upper pons. Typically a butterfly or triangular shaped symmetrical midline lesion rimmed by areas with preserved myelination.

2.9.6.3 Histology:

No inflammation, macrophages are present, preserved axons; axonal swelling may be present, viable neurons in affected areas, transverse (pontocerebellar) fibers are more affected than the rostral-caudal (cortical spinal and cortical bulbar) fibers. (Kar-Ming Fung 2006)

2.9.7 Infection:

Just like any other organs in the human body, the central nervous system can be infected by all kinds of infectious agents including prion, virus, bacteria, fungus, and parasites.Similar to other organs of the body, infection of the CNS triggers inflammation in most cases. There are, however, some unique features regarding infections of the CNS:

2.9.8 Encephalitis without identified infectious agents.

This is a class of diseases featured by inflammation of the CNS that closely suggest infections but the infectious agents have never been isolated. Raussmussen encephalitis is a good example. Infections of the central nervous system come in 4 major patterns; diffuse, localized, multifocal and disseminated **(**infection form a primary source outside the CNS). There are important factors take parts in casting the final pathologic features:Virulence

of the agent, Route of entry and Systemic factorssuch as compromised immunity (johns et al 2012).

2.9.8 Infections of the CNS can be classified into the following categories:

Meningitis, meningoencephalitis encephalitis, Myelitis, Encephalomyelitis Choroidplexitis, subdural empyema and epidural abscess, cerebritis Ventriculitis and ependymitis and brain abscess (johns et al 2012).

2.10 Biological effect:

The biological effects of ionizing radiation are the combined result of direct absorption of energy at molecular level and the indirect oxidative damage produced by the reactive oxygen species ("free radicals") produced through a process called water radiolysis. (i.e. direct and indirect effects). Direct and indirect effects may lead to recognizable damage particularly when they affect molecules of biological importance. The DNA molecule is the principal target for the biological effects of ionizing radiation, including cell killing and mutations leading to non-lethal cell transformation. Cellular damage from ionizing radiation depends on the type of radiation, the energy deposition rate, and the distribution through the tissue. Biological effects also depend on the radiosensitivity of the tissue exposed. Two kinds of effects of radiation on tissues are observed:

-Deterministic effects (or "tissue reactions") occur when a large number of cells have been damaged and as a result of that, the tissue structure or function is affected. These effects occur at doses above a certain threshold, with the frequency and the severity of effects increasing sharply above this threshold. To the extent that the organism is able to compensate for the loss of cells, the harm may be temporary. Examples of deterministic effects are nausea, diarrhoea, skin damage and sterility (UNSCEAR 2006).

-Stochastic effects occur when cells are not killed, but are modified. Some of the changes may persist in daughter cells. Examples of stochastic effects

are cancer in the individuals who have been exposed to radiation if the transformation occurred in a somatic cell, and hereditary diseases in descendants of individuals exposed, if the transformation occurred in a germ cell (i.e. oocytes or sperm cells) . Ionizing radiation is a complete carcinogen since it can act to initiate, promote and progress cellular changes that lead to cancer. The dose of radiation received by an individual affects the probability of cancer, but not its aggressiveness. Radiation-induced cancer is indistinguishable from cancer from other causes. The probabilistic nature of this risk means that children have more time to accumulate exposures and damage, and more time after exposure to develop the disease. Epidemiological evidence that low doses of radiation may induce cancer in humans is only available for doses higher than 100 mSv. A linear non-threshold (LNT) hypothesis is applied to calculate risks for lower radiation doses. There is no direct epidemiological evidence of radiation-induced hereditary effects in humans, although animal studies suggest that they might occur. Emerging evidence suggests that radiation exposure may increase the risk of cardiovascular and possible other non-cancer diseases. However, the mechanisms involved are still unclear and further research is needed before considering this effect as part of the radiation detriment (UNSCEAR 2006).

The radiation exposure from a single diagnostic procedure is usually small. However, many people undergo radiological examinations, some of them rather frequently, making these procedures the highest human-made source of radiation exposure. Because of the increased lifetime risk per unit dose for children, the potentially higher doses, and the increasing frequency of paediatric computerized tomography (CT) examinations, diagnostic procedures that use radiation can lead to a small, but non-negligible, increase in risk of cancer. While these procedures are undisputedly beneficial, the magnitude of exposure of children can often be reduced without significant loss of information. An area of special concern is the unnecessary use of

radiation imaging when clinical evaluation or other imaging modalities could provide an accurate diagnosis (justification). Methods for dose reduction should be applied to optimize protection, keeping the dose commensurate with the medical purpose (optimization of radiation protection). JUSTIFICATION and OPTIMIZATION are the two principles of radiation protection in medical exposures to ionizing radiation. From a radiological protection perspective, clear justification of radiological examinations for children and young adults is essential. In addition, dose protocols and techniques have to be adapted to children and young adult patients while providing the required diagnostic information, thus optimizing protection (Brenner DJ et al 2001).

The risks of CT are usually small and the risk-benefit balance favors the benefit when CT is used appropriately. However, this risk/benefit balance does no more favor the benefit when pediatric CT scans are performed without a clear clinical indication or when patients receive a higher dose than necessary because adult CT settings are used for children. Two studies indicate that radiologic imaging is often unnecessary in children who present to the Emergency Department (ED) with headache or wheezing. - Investigators retrospectively reviewed the records of 364 children (age range, 2–5 years) who presented to one Emergency Department in Washington DC with a chief complaint of headache. Initial history and physical exam showed that 84% of children had headaches that were secondary to an apparent acute illness (usually viral, respiratory, or febrile), trauma, or a known underlying condition (e.g. ventriculo-peritoneal shunt, brain tumor, or chronic non-neurological disease). Among the remaining 58 children with primary headache, 16 underwent head computed tomography (CT) scans; only 1 child had an abnormal finding (brainstem glioma), and this child's history had details suggestive of intracranial pathology. Among children with primary headache who had follow-up information available, no

neurological conditions were subsequently discovered (mean follow-up, 28 months). -In a second study, investigators studied a prospective cohort of 526 patients (age range, 0–21 years) who presented to one ED in Boston with wheezing and who underwent chest radiography for possible pneumonia. Only 5% of children had radiographically confirmed pneumonia as determined by radiologists. Fifteen percent of the cohort received antibiotics for pneumonia, and 36% were hospitalized. Fever (38°C) was significantly associated with increased risk for radiographic pneumonia (positive likelihood ratio, 2.03). The incidence of radiographic pneumonia in children who did not have fever was very low (2%). Oxygen saturation Comment: Head CT scans are expensive, carry some long-term risk associated with radiation exposure, and, in this study, did not contribute to the diagnosis of pathology in children without suspicious findings on history or physical exam, even in young children. Similarly, the utility of chest radiography for diagnosing pneumonia in children with wheezing is low, especially in children without fever. Moreover, many consider pneumonia a clinical, not radiographic, diagnosis. In these two common ED situations, careful history and physical exam can obviate the need for these radiologic tests (Lateef TM et al2009).

2.11 Risk from x-ray radiation:

The United Nation Scientific Committee on the Effects of Atomic Radiation (UNSCEAR, 2000).

Has highlighted that the worldwide there about 93 million CT examination performed annually at a rate of about 57 examination per 1000 persons. UNSCEAR also estimated that CT constitutes about 5% of all X-ray examination worldwide will accounting for about 34% of the resultant collective dose. In the countries that were identified as having the highest levels of healthcare, the corresponding figures were 6% and 41% respectively. New advancement of the CT has also led to great increase of

the radiation dose to the patients. The use of multi-slice computed tomography (MSCT) has aggravated the scenario with the increasing of collective dose of CT examinations because the MSCT produces higher dose to the patients compared to single slice CT (SSCT) (Hunold et al. 2003).

2.12 Previous Study:

Sawsan 2010 The use of CT in medical diagnosis delivers radiation doses to patients that are higher than those from other radiological procedures .Lake of optimized protocols could be an additional source of increased dose. The aimof this study was to measure radiation doses in CT examinations of the adults in three Sudanese hospitals. Details were obtained lrom approximately 160 CT examinations carried out in 3 hospitals (3 CT scanners).

The effective dose was calculated for each examination using CT dose indices, exposure related parameters and CTDI-to-effective dose conversion factors. CT air kerma index (CTDl) and dose length products (DLP) determined were below the established international reference dose levels. The mean effective doses in this study for the head, chest, and abdomen are 0.82, 3.7 and 5.4 mGy respectively. These values were observed that the effective dose per examination was lower in Sudan than in other countries. The report of a CT survey done in these centers indicates that the mean DLP values for adult patients were ranged from 272-460 mGycm (head) 195-995 mGycm (chest), 270-459 mGycm (abdomen). There are a number of observed parameters that greatly need optimization, such as minimize thescan length, without missing any vital anatomical regions, modulation of exposure parameters (kV, mA, exposure time, and slice thickness) based on patient size and age, Another possible method is through use of contrast media only to optimize diagnostic yield. The last possible method is the use of radio protective materials for protection .however, in order to achieve the above optimization strategies; there is a great demand to educate CT personnel on the effects of scan parameter settings on radiation dose to patients and image quality required for accurate diagnosis.

IoannisIakovou et al2008 In recent years the volume of diagnostic procedures involving the use of ionizing radiation has rapidly increased. Technological advances in computed tomography (CT) equipment, with the

availability of multi-slice acquisition and the introduction of hybrid systems, have made this modality extremely popular among other diagnostic procedures, especially in pediatrics and as a screening procedure for asymptomatic adults. Physicians' major radiation-related concern regarding diagnostic imaging, is possible iatrogenic malignancy.

According to major national and international organizations responsible for evaluating radiation risks, there is no low-radiation Threshold for inducing cancer. This means that no amount of radiation should be considered absolutely safe. Although, the risk of radiation-induced cancer is much smaller than the risk of cancer from natural sources, it can become a public health concern if large numbers of the population undergo increased numbers of CT screening procedures that may even be of uncertain benefit. In order to reduce the overall radiation dose from CT procedures in the population, it is important to keep radiation dose as low as reasonably achievable, by adjusting scanner parameters separately for each individual. In addition, it is crucial to eliminate the inappropriate referrals for CT tests and choose other diagnostic modalities, such as sonography, magnetic resonance imaging systems, or nuclear medicine procedures.

While CT remains an important diagnostic procedure, it is important for health care community to reconsider the indications of a CT scan, especially in children and asymptomatic patients.

Physicians who prescribe CT could assess its use on a case-by-case basis. When used prudently and optimally, CT remains a very valuable imaging modalitiy for both children and adults.

E J HALL et al 2008 ABSTRACT. In recent years, there has been a rapid increase in the number of CT scans performed, both in the US and the UK, which has fuelled concern about the long-term consequences of these exposures, particularly in terms of cancer induction. Statistics from the US and the UK indicate a 20-fold and 12-fold increase, respectively, in CT

usage over the past two decades, with per caput CT usage in the US being about five times that in the UK. In both countries, most of the collective dose from diagnostic radiology comes from high-dose (in the radiological context) procedures such as CT, interventional radiology and barium enemas; for these procedures, the relevant organ doses are in the range for which there is now direct credible epidemiological evidence of an excess risk of cancer, without the need to extrapolate risks from higher doses.

Even for high-dose radiological procedures, the risk to the individual patient is small, so that the benefit/risk balance is generally in the patients' favour. Concerns arise when CT examinations are used without a proven clinical rationale, when alternative modalities could be used with equal efficacy, or when CT scans are repeated unnecessarily. It has been estimated, at least in the US, that these scenarios account for up to one-third of all CT scans. A further issue is the increasing use of CT scans as a screening procedure in asymptomatic patients; at this time, the benefit/risk balance for any of the commonly suggested CT screening techniques has yet to be established.

G Breiki et al 2008 Computed tomography (CT), is an X-ray procedure that generates high quality cross-sectional images of the body, and by comparison to other radiological diagnosis, CT is responsible for higher doses to patients.

The aim of this work is to study the CT practice in some CT units in different hospitals in Egypt, in order to investigate the radiation doses imparted topatients during CT examinations and image quality. Dose measurements were performed for the most common applied CT examinations covering radiation sensitive organs in the head and trunk regions.Selected CT examinations are; routine head, routine chest, routine abdomen and routine pelvis. Computed Tomography Dose Index (CTDI) wwas calculated for each scanner from an average of three measurements in the head phantom and another three measurements in the body phantom.

DLP values wereestimated for each type of examination. Mean values of CTDIw had a range of 36.0-69.0 mGy for head and11.0-30.0 mGy for chest, abdomen and pelvis examinations.

Organ dose and hence effective dose, calculated using Monte Carlo simulation technique. The effects of selecting tube KV and mAs on both spatial resolution and low contrast detectability were examined for two groups of KV values (90 and 120), the mAs values were degraded from 100 to 300 mAs in 100 mAs interval in first case, and from 50 to 300mAs, in 50mAs interval in second case.

L. Sadri 2013*Background*: Paentradiaon doses from computed tomography (CT) are increasing due to the number of CT examinaons performed every day. The aim of this study was assess and evaluate paentradiaon doses for adult's common CT examinaons to derive local diagnosc guidance levels for common CT examinaons. *Materials and Methods*: Volume and weighted computed tomography dose index (CTDI) and dose length product (DLP) of four common CT examinaons including head, head sinus, chest, abdomen and pelvis were measured for 8 different CT scanners using standard head and body phantoms. The image quality of acquired scan images were assessed according to European Commission (EC) image quality criteria guidelines.

Results: The mean measured CTDI vol,wfor head base; head cerebrum, head sinus, chest and abdomen-pelvis were 71.8, 29.7, 35.8, 9.8 and 12.9 mGy, respecvely. The DLP for head, head sinus, chest and abdomen -pelvis were 500, 371, 225 and 482 mGy.cm. The results of our study were shown more paent doses in terms of DLP for head sinus in compare with other studies while CTDI w wvalues for head base and sinus were higher than EC measurements.

Conclusion: The great variaons of CTDIand DLP observed among hospitals and relavely high values of DLP in some centers are evidence that radiaon

doses of paents from CT examinaons is not fully opmized. It was concluded that future studies of connuesopmizaon to minimize the dose without affecng image quality are needed.

P C Shrimpton 2004 This report summarises work undertaken in support of a European Commission (EC) Concerted Action on CT that has included both a review and further development of the framework for CT dosimetry. The system previously established by the EC for reference doses in CT (with the quantities *weighted CTDI(CTDI)* and *dose-length product (DLP)*)has been expanded to include subsequent developments in CT technology, such as multi-slice scanners and the recommendation for display of *volume CTDI (CTDIw)* on the scanner console.

New Monte Carlo calculations for CT have been carried out to supplement the relative lack of normalised organ dose data available for paediatric patients. Series of simulations have been completed for 3 particular models of scanner and 6 mathematical phantoms representing ages newborn, 1y, 5y, 10y, 15y and adult. Analysis of these results has confirmed the trends for an enhancement of the doses to small children relative to those to adults under similar conditions of CT exposure, by factors up to 2.6 in the case of the newborn patient, depending on scanner model and region of scan. A new comprehensive framework is proposed for assessing organ doses in CT based on coefficients relating them to corresponding values of *CTDI w vol* in the standard (head or body) CT dosimetry phantoms. This approach would potentially provide a single set of dose coefficients for each standard patient age for universal application to all scanner models. Some initial values are presented of effective dose normalised both to *CTDI w*and*DLP* for combinations of standard examination and phantom age.

Chapter three

Materials and Methods

Chapter three

Materials and Methods

3-1Materials Used:

Computed Tomography (CT), 64 slice Toshiba	Royal Care International Hospital
Computed Tomography (CT), 64 slice Philips	Dar Alelag Specialized Hospital.
Computed Tomography (CT), 128 slice Toshiba	East Nile Hospital.

3-2 Type of study:

This was descriptive study

3-3 Place and time of study:

This study was performed at Radiology department of Royal Care International Hospital,DarAlElaj Specialized Hospital and East Nile Hospital during the period from (April-2016 up to May -2017).

3-4 Study sample:

This study included 120 patients all selected from patients (1-17 years) who were referred to the CT scan department for brain examinations.

3-5 Study variables:

The variables that were collected from each subject included gender, Age from (1 up to 17 years).

CT machines

CT scanners that participated in this study are helical CT scanners in three hospitals. All scanners displayed volume Computed Tomography Dose Index (CTDIvol) and Dose Length Product (DLP). The data were collected from each CT scanner (manufacture, model, year of installation, and detector type). The CT machine characteristics are presented in Table 1. The data was collected from the following radiological departments: Royal Care

International Hospital, Dar Al Elaj Specialized Hospital and East Nile Hospital. All quality control tests were performed to the machines prior to any data collection.

3-6 Data collection:

The data were collected by account the number of CT scans in master data table (appendices)

3-7 Dose Measurement :

Radiation dose indicators CTDIvolv and DLP can be obtained from a dose summary page, which includes information about the CT exam. CTDIvol does allow the comparison of scan protocols or scanners and is useful for obtaining benchmark data to compare techniques, but it's not so good for estimating patient dose . DLP, an indicator of the dose imparted to the patient, is calculated by multiplying CTDIvol times the scan length. In addition to being affected by the issues associated with CTDIvol , DLP can be problematic in a limited scan range .

3-8 Calculation of Effective dose :

CT scanners record the radiation exposure as a DLP in mGy.cm. The reviewing

radiologist can Multiply this by Conversion Factor (CF) to convert it to effective dose in mSv.

3-9 Analysis of data:

All dose parameters will registered from the display monitor in CT scan and they use in calculation for the effective dose using conversion factor to the brain and chest. Then used as input to the Microsoft excel and SPSS software for analysis.

Chapter Four

Results

Table 4.1 show statistical parameters for patients in three hospitals:

	Mean	***Median***	***STD***	***Min***	***Max***
Age	6.49	6	5.30	1	17
KVp	116.03	120	10.08	80	150
mAs	301.65	250	169.73	25	601
DLP	1046.03	901.90	663.77	24.70	77.50
CTDIvol	45.02	47.40	24.33	0.90	77.50
Slice Thickness	1.05	0.86	0.563	0.50	2.50
Effective Dose	19.56	16.86	12.4	0.46	66.60

Table 4.2 show statistical parameters for patients in Dar Al ElajSpecializeed Hospital:

	Mean	***Median***	***STD***	***Min***	***Max***
Age	5.10	3	4.82	1	17
KVp	115.71	120	8.30	100	120
mAs	372.29	325	164.18	75	601
DLP	1082.29	954.75	750.78	55.2	3561.5
CTDIvol	45.46	39.57	27.27	2.95	77.50
Slice Thickness	1.22	1.23	0.46	0.56	1.88
Effective Dose	20.23	17.85	14.03	1.03	66.60

Table 4.3 show statistical parameters for patients in Royal Care Hospital:

	Mean	***Median***	***STD***	***Min***	***Max***
Age	10.60	10	5.22	3	16
KVp	120	120	0.00	120	120
mAs	202.60	226	62.87	100	250
DLP	1307.26	1435.30	540.15	518.60	1999.7
CTDIvol	47.70	33.50	27.33	21.90	77.30
Slice Thickness	1.35	0.75	10.5	0.50	2.50
Effective Dose	24.44	26.84	10.10	9.69	37.39

Table 4.4 show statistical parameters for patients in East Nile Hospital:

	Mean	***Median***	***STD***	***Min***	***Max***
Age	8.88	10	5.34	1	16
KVp	115.63	120	15.04	80	150
mAs	147.19	150	40.67	25	187
DLP	869.19	868.10	377.92	24.70	1389
CTDIvol	43.01	47.60	14.34	0.90	57.20
Slice Thickness	0.50	0.50	0.00	0.50	0.46
Effective Dose	16.25	16.42	7.06	0.46	25.97

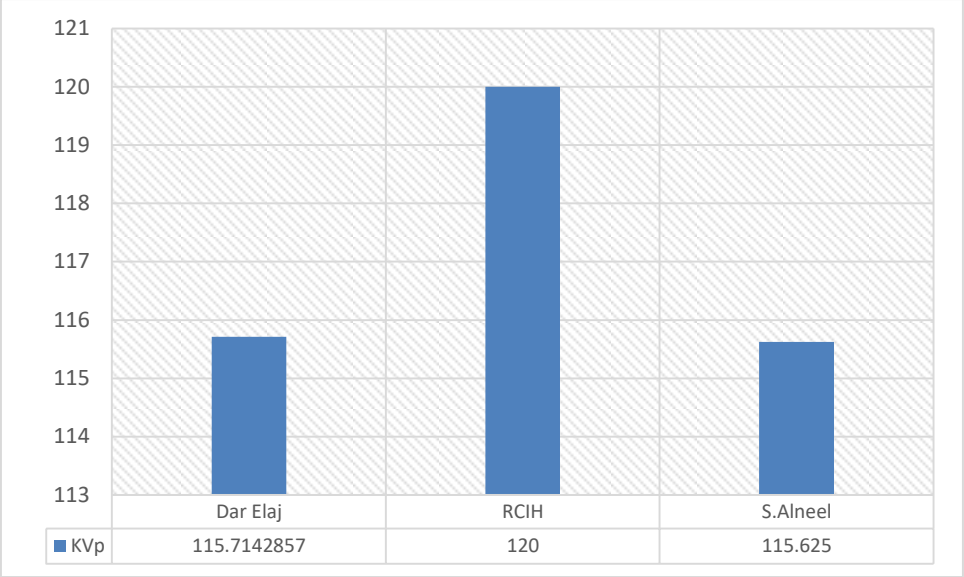

Figure4.1 show comparison of KVp between three hospitals:

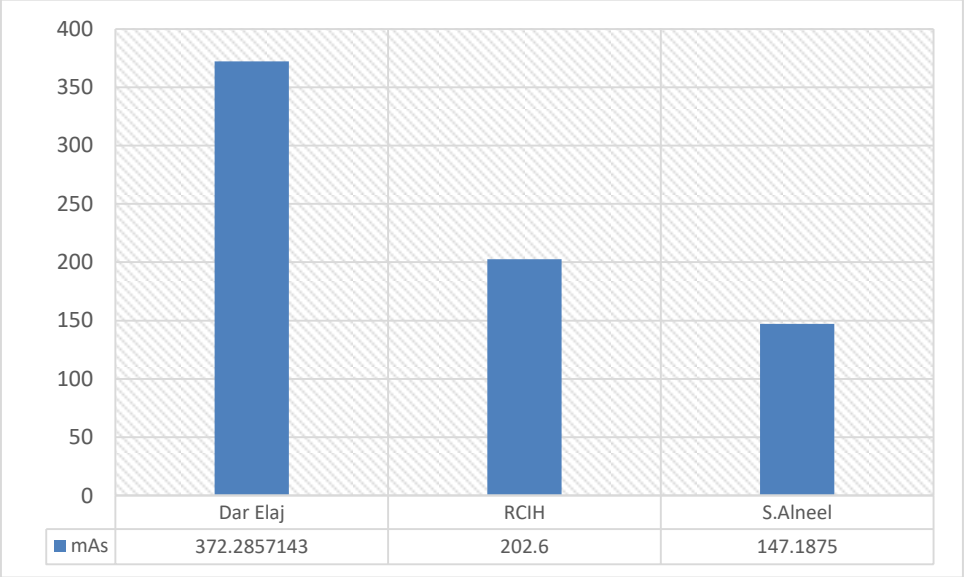

Figure4.2show comparison of mAs between three hospitals:

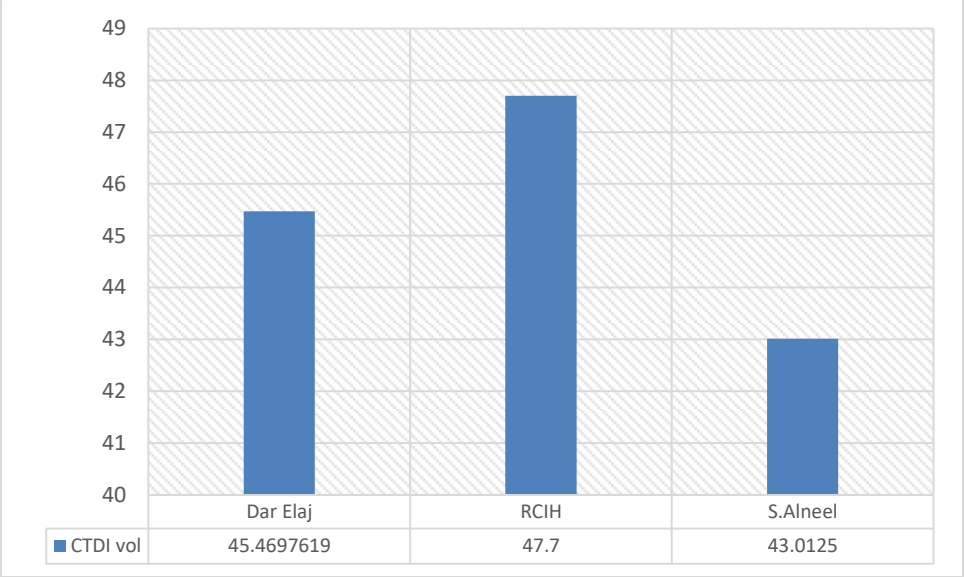

Figure4.3 show comparison of CTDIvol between three hospitals:

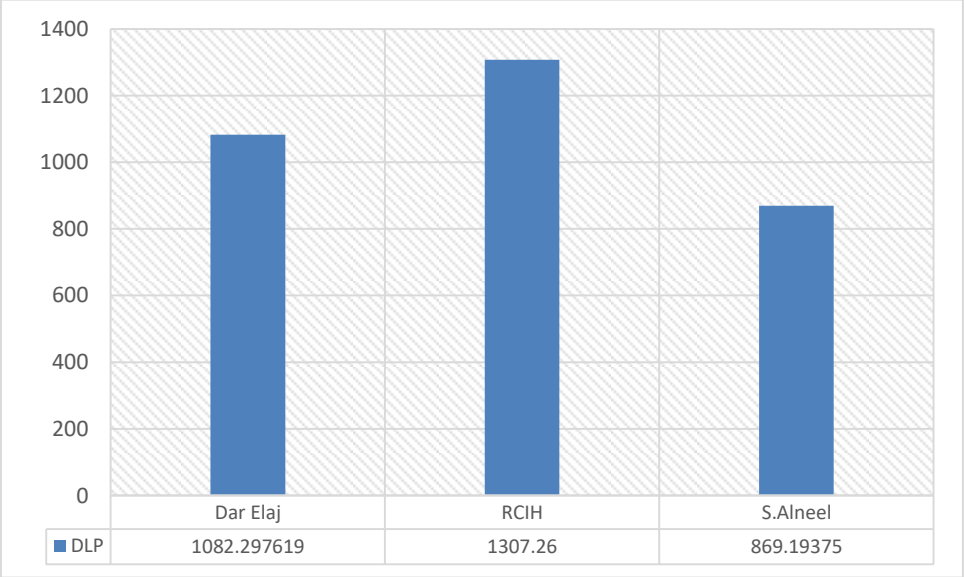

Figure4.4 show comparison of DLP between three hospitals:

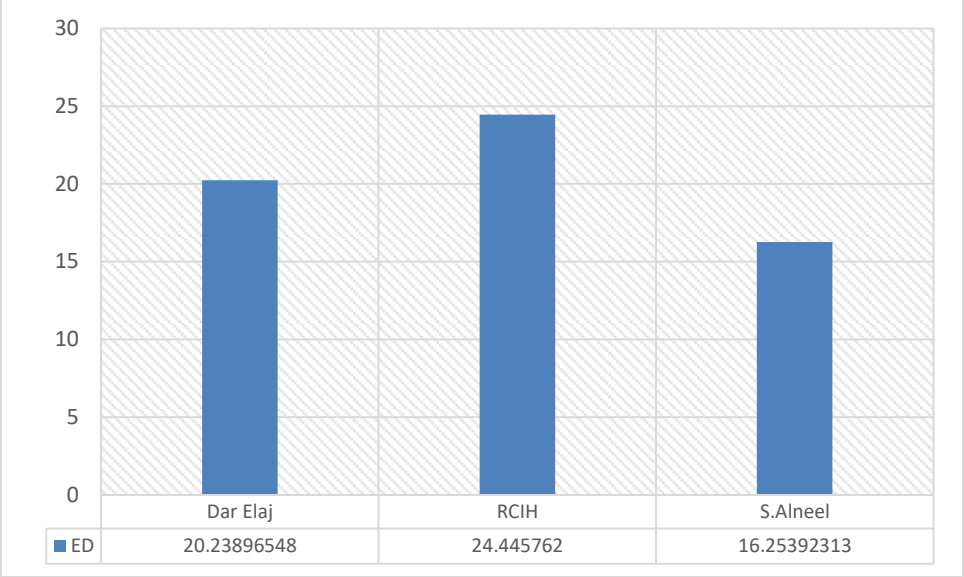

Figure4.5 show comparison of effective dose between three hospitals:

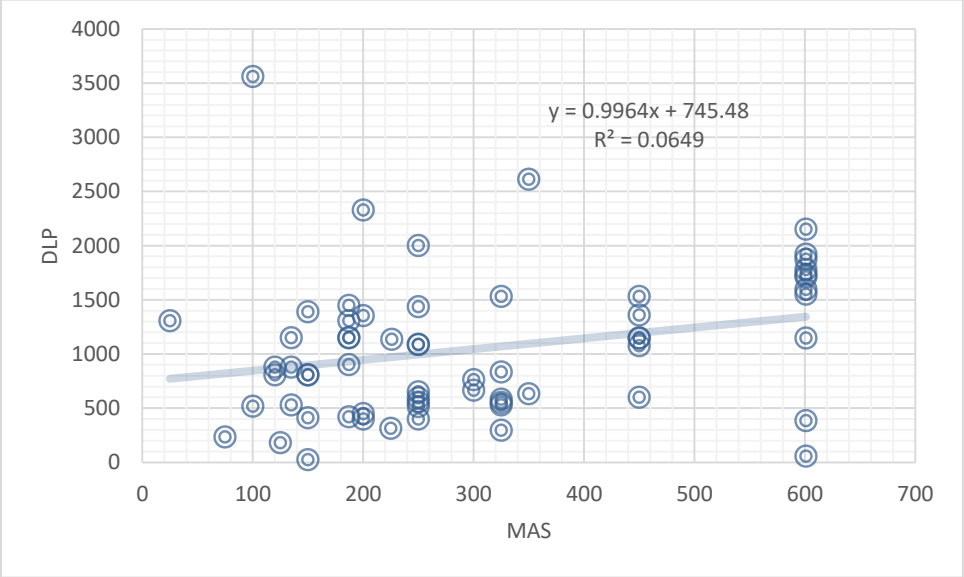

Figure4.6 show Correlation between mAs with DLP in three hospitals:

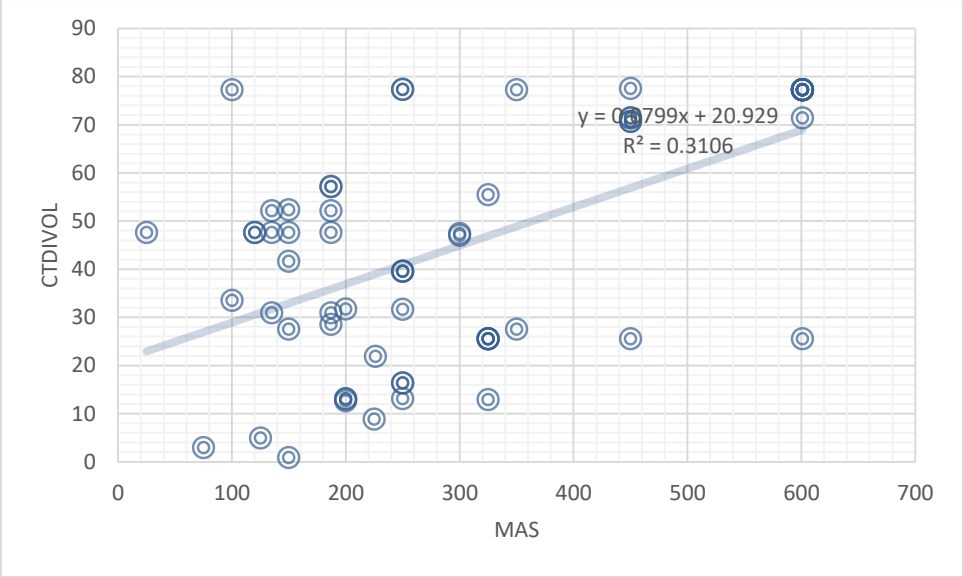

Figure4.7 show Correlation between mAs with CTDIvolin three hospitals:

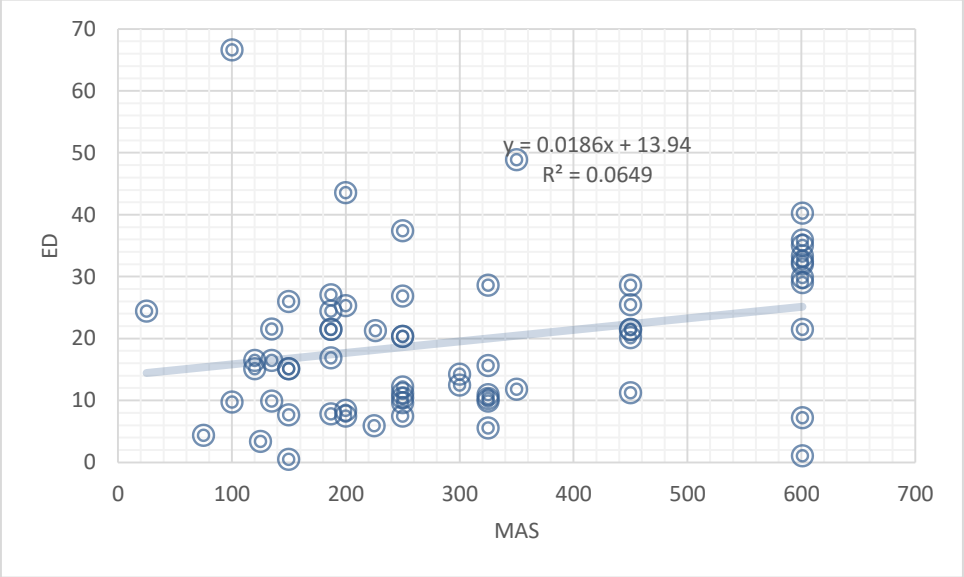

Figure4.8 show Correlation between mAs with effective dose in three hospitals:

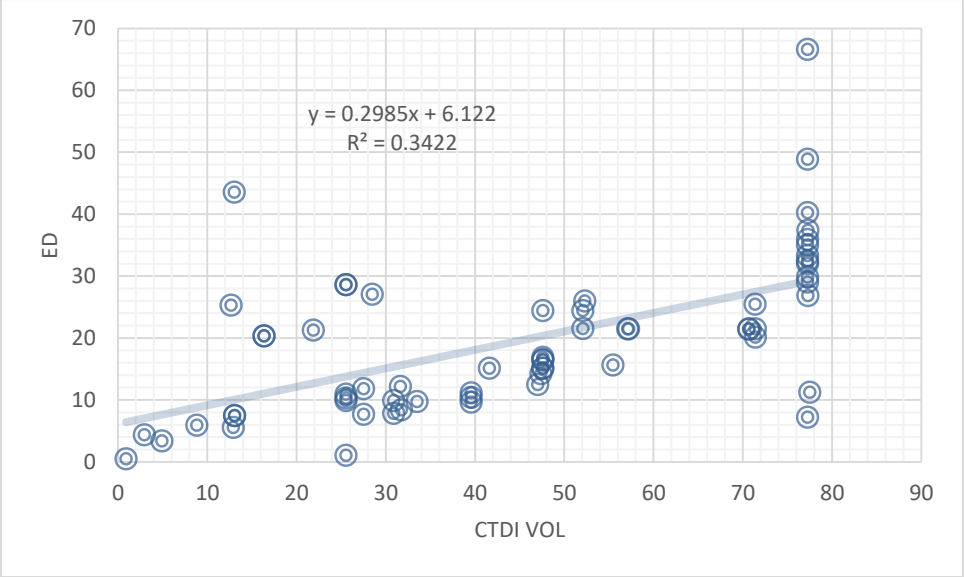

Figure4.9 show Correlation between effective dose with CTDIvolin three hospitals:

Chapter Five

Discussion, Conclusion and Recommendation

Chapter Five

Discussion, Conclusion and Recommendation

5.1 Discussion:

This study done to estimate of pediatric Dose during Computed Tomography (CT) Examinations in three hospital in Khartoum state.

The study found that the statistical parameters for patients in the three hospitals for age, KVp, mAs, DLP (mGy.cm), CTDIvol (mGy), Slice Thickness and effective dose (mSv) using Mean, Median, STD, Min and Maximum, and for Age the mean (Mean ± SD) was 6.49±5.30 and for KVp 116.03± 10.08 and for mAs, DLP, CTDIvol, Slice thickness and effective dose was 301.65±169.73, 1046.03±633.77, 45.02±24.33, 1.05±0.56 and 19.56±12.4 respectively as shown in table (4.1).

The study found that the statistical parameters for patients in Dar Al Elaj Specialized Hospital for age the mean (Mean ± SD) was 5.10±4.82 and for KV 115.71±8.30 and for mAs, DLP, CTDIvol, Slice thickness and effective dose was 372.29±164.18, 1082.29±750.78, 45.46±27.27, 1.22±0.46and 20.23±14.03 respectively as shown in table (4.2).

The study found that the statistical parameters for patients in Royal Care International Hospitalfor for age, KVp, mAs, DLP, CTDIvol, Slice Thickness and effective dose using Mean, Median, STD, Min and Maximum, and for Age the mean (Mean ± SD) was 10.60±5.22 and for KVp 120±0.00 and for mAs, DLP, CTDIvol, Slice thickness and effective dose was 202.60±62.87, 1307±540.15, 47.70±27.33, 1.35±10.5 and 24.44±10.10respectively as shown in table (4.3).

The study found that the statistical parameters for patients in East Nile Hospital for age, KVp, mAs, DLP, CTDIvol, Slice Thickness and effective dose using Mean, Median, STD, Min and Maximum, and for Age the mean (Mean ± SD) was8.88±5.34 and for KVp 115.63±15.04 and for mAs, DLP, CTDIvol, Slice thickness and effective dose was 147.19±40.67,869.19

±177.92, 43.01±14.34, 0.50±0.00 and 16.25±7.06respectively as shown in table (4.4).

The study found that the comparison of KVp between the three hospital where the higher value of KVp was at Royal Care were almost equal at Dar Al Elaj and East Nile Hospitals as shown in figure (4.1).

The study found that the comparison of mAs between the three hospital where the higher value of mAs was at Dar Elaj hospital and Lower at East Nile hospital as shown in figure (4.2).

The study found that the comparison of CTDIvol between the three hospital where the higher value of CTDIvol was at Royal Care Hospital and Lower at East Nile Hospital as shown in figure (4.3).

The study found that the comparison of Dose Length Product and effective dosebetween the three hospital where the higher value was at Royal Care Hospital and Lower at East Nile Hospital respectively as shown in figure (4.4) and (4.5).

The study found no linear association between mAs with Dose Length Product DLP were the R^2 the value of correlation (R^2=0.06) as shown in figure (4.6).

The study found no linear association between mAs with CTDIvol and effective dose ED were the R^2 the value of correlation (R^2=0.31) and (R^2=0.064) respectively as shown in figure (4.7) and (4.8).

The study found no linear association between effective dose ED with Computed Tomography Dose Index Volumetric CTDIvol were the R2 the value of correlation (R2=0.34) as shown in figure (4.9).

Automatic Exposure Control (AEC) devices that are nowadays available in modern equipment module the tube current as function of the table position along the z-axis and of the image quality requested by the radiologist. Such increase it in obese and overweight patients, tending to maintain the image quality constant. Therefore, radiologists using these devices should think on

terms of image quality and not of the tube current. Mulkens et al. 2005 showed that systems based on both angular and z-axis modulation reduce the mean tube current by 20% – 68% when applied to the standard MDCT protocols at constant tube current. With such systems, these authors also showed a good correlation between the mean effective tube current and patient's body mass index (BMI), with an adaptation in obese and overweight patients leading to reference tube current level being exceeded. These devices, which are only a partial response to the issue of the radiation dose. Survey studies have shown that the collective doses have increased as MDCT has replaced SDCT. However, the radiation dose has been optimized over the last decade, mainly through AEC devices and reasonable use of tube current and tube voltage preset. This was achieved thanks to the technological improvements and willpower of several study groups to investigate the effect of dose reduction in terms of image quality and diagnostic performance. Nevertheless, as both the number of examinations and number of clinical indications for CT increase, a major effort should be made in order to optimize the radiation dose. In addition, as survey studies have shown that great variations in doses among institutions remain, a supplementary effort should be made in order to recommend standardized acquisition protocols. One of the several problems limited the study: first one is CT requested form, which was not included ideal clinical information, and some more time not justified and all cases referred for e.g. CT abdomen pelvis, brain and upper chest CT, chest abdomen CT, etc.

5.2 Conclusion:

This study done to estimate of pediatric Dose during Computed Tomography (CT) Examinations in three hospital in Khartoum state Dar Al Elaj Specialized Hospital, Royal Care International Hospital and East Nile Hospital in period from April to November 2016 and The study shows that there is a large dose variation between different CT scan units that used for data collection. and the results show that the mAs values was higher in in Dar Elaj hospital than other hospitals, and in case of KV, CTDIvol (mGy), DLP (mGy.cm) and effective dose (mSv) was higher in Royal Care then Dar Elaj then East Nile .

In correlation of mAs with other variables found that the relation of mAs with DLP and effective dose was week relation, and mAs with CTDIvol was moderate.

And the correlation the ED with CTDIvol show that there is moderate relation between them. So in this study the dose higher in Royal Care International Hosspital (RCIH) then Dar ElajSpecilized Hospital (DSH) and the dose was lower at East Nile .

The main dose variations in the same CT unit could be attributed to the different techniques, which justify the important of use radiation dose optimization technique and technologists training. Dose reduction strategies must be well understood and properly used.

5.3 Recommendations

- CT operators must optimize the patient dose for patient to reduce patient cancer risks. Should be uses the best strategies available for reducing radiation dose to allow for mAs reduction in relation to the patient's age and size.
- Implementation of automatic exposure control systems by the manufacturers.
- Achieve optimization through; the design of dose efficient equipment, the optimization of scan protocol and improvement of referring criteria.
- The radiologists and CT technologists must be trained to adapt CT scanning techniques based on clinical indications and to assess associated radiation doses with different scanning parameters.

References:

Brenner DJ, et al. Estimated risks of radiation-induced fatal cancer from pediatric CT. American journal of Roentgenology, 2001, 176(2):289-96.

DH.Salat et al., (2010). Age-Associated Alterations in Cortical Gray And White Matter Signal Intensity and Gray to White Matter Contrast {WWW} Available From Http://Www.Ncbi.Nlm.Nih.Gov/Pubmed/?Term=Rosas%20H%5Bauth%5D. 5.1.2015

European Commission. European guidelines on quality criteria for computed tomography EUR 16262 En, Luxemburg (1999).

Goldman LW. Principles of CT: radiation dose and image quality. J Nucl Med Technol. 2007;35:213–225.

Johns Hopkins.Simeon Margolis, M.D., Ph.D.The Editorial Staff at Healthcommunities. 17 Jan 2012

Catherine and Carolyn (2000) MRI in practice.Second edition. London: Blackwell.

Franke K (2007).Estimating The Age of Healthy Subjects from T1Weighted MRI Scans Using Kernel Methods. University Of Jena, Jena, Germany {WWW} Available From Http://Www.Ncbi.Nlm.Nih.Gov/Pubmed/20070949. 25.1.2015

Lee S, et al. Changes in the pattern of growth in stature related to prenatal exposure to ionizing radiation. International radiation biology, 1999, 75(11):1449-58.

International Commission on Radiological Protection (ICRP). Radiation and your patient: a guide for medical practitioners. Available at www.icrp.org/docs/Rad_for_GP_for_web.pdf - accessed December 2009

Lateef TM et al. Headache in young children in the emergency department: Use of computed tomography. Pediatrics. 2009; 124:e12.

Mathews B et al. Clinical predictors of pneumonia among children with wheezing.Pediatrics 2009. 124:e29.

Keith J. Strauss Marilyn J. Goske Image Gently: Ten Steps You Can Take to Optimize Image Quality and Lower CT Dose for Pediatric Patient, AJR 2010; 194:868-873.

Rehani M, Berry M. Radiation doses in computed tomography (Editorial). Br. Med. J. 320, 593-594. 2000.

Ge Y Grossman 'Et Al.' 2002 Age-Related Total Gray Matter And White Matter Changes In Normal Adult Brain. Part I: Volumetric MR Imaging Analysis {WWW} Available From Http://Www.Ncbi.Nlm.Nih.Gov/Pubmed/12223373#26/6/2014

Gilmore JH, Et Al.; 2006.3 Tesla Magnetic Resonance Imaging of the Brain in Newborns.psychiatry research. 132(1):81–85.

KanarAlkass et al., (2009) Age Estimation in Forensic SciencesKar-Ming Fung (2006) Neuropathology Lecture Note Kim DM, 'Et Al.' (2002). MR Signal Intensity of Gray Matter/White Matter Contrast and Intracranial Fat: Effects of Age and Sex. {Www} Available From Http://Www.Ncbi.Nlm.Nih.Gov/Pmc/Articles/PMC25854 20/6/12/2014

M.A. Brown and R.C.Semelka 2003. C. MRI: Basic Principles & Applications. 3rd Ed. New Jersey. John Wiley & Sons, Inc., Hoboken

Maria and Leslie (2006) a Text Book ofNeuroanatomy London: Blackwell

Valerie C. Scanlon (2007) Essentials of Anatomy and Physiology. Fifth Edition – Philadelphia: F.A.Davis Company

UNSCEAR (2006).Sources, effects and risks of ionizing radiation.United Nations Scientific Committee on the Effects of Atomic Radiation, United Nations, New York, NY. Available at: www.unscear.org/unscear/en/publications/2006_1.html– accessed December 2009

Wallaby 2011. Which Factors Can Influence The Signal Intensity In MRI?{Www}.Available From Http://Www.Thescienceforum.Com/Physics/25012-Factors-CanInfluence-Signal-Intensity-Mri.Html 28/10/2014

Appendix:

Sample of data collection sheet:

Exam	Gender	Organ	Age	KvP	mA	Exposure time /s	CTDIvol (mGy)	DLP (mGy-cm)