Sudan University of science and Technology

College of Graduate Studies

Estimation of Radiation Effective dose for pediatric patients in Brain Computed tomography

تقدير الجرعة الإشعاعية المؤثرة للأطفال لتصوير الدماغ بالأشعة المقطعية

A Thesis submitted for The Requirements of Partial Fulfillment of M.Sc. Degree in Medical Physics

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الآية

قال تعالى:

﴿ قَالَ لَهُ مُوسَى هَلْ أَتَّبِعُكَ عَلَى أَنْ تُعَلِّمَنِ مِمَّا عُلِّمْتَ رُشْدًا *قَالَ إِنَّكَ لَنْ تَسْتَطِيعَ مَعِيَ صَبْرًا *وَكَيْفَ تَصْبِرُ عَلَى مَا لَمْ تُحِطْ بِهِ خُبْرًا ﴾

(الكهف: 66 – 68)

Dedication

I humbly dedicate this piece of work to my loving parents, who have been my source of inspiration and gave me strength when i thought of giving up, who continually provide their moral, spiritual, emotional, and financial support, and to my brothers, sisters, relatives, mentor, friends, and classmates who shared their words of advice and encouragement to finish this study.

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Abstract

Computed Tomography (CT) of the pediatric for brain it used increasingly. Particularly in oncological patients. How to use CT scan rightly and to reduce the radiation dose as much as possible have been the critical issues of concern in the field of clinical imaging technology. In diagnostic radiology, periodic dose assessments are carried out to encourage the optimization of the radiation protection of patients. This study estimated radiation dose to 51st pediatric patients in Modern Medical Center by undergoing GE Optima CT250 series - 16 slices. The result of this study the Linear Regression equation between $CTDI_{vol}$ and SSDE which is

$$SSDE = -0.002+0.93(CTDI_{vol})$$

And mean ± SD for effective dose it's 49.69 msv ± 29.82 msv comparing with Korean stander which is 1.5 msv ± 0.2 msv it's high . This study concludes to deference referring to not used pediatrics protocol.

المستخلص

التصوير المقطعي المحوسب (CT) للأطفال بالنسبة للدماغ مستخدم بشكل متزايد ، لا سيما في مرضى الأورام . كيفية ستخدام الأشعة المقطعية بشكل صحيح ، و الحد من جرعة الأشعاع قدر الإمكان كانت من القضايا الهامة و المقلقة في مجال تكنلوجيا التصوير السريري . في الأشعة التشخيصية ، يتم إجراء تقييم للجرعة الدورية لتشجيع تحسين الحماية الإشعاعية للمرضى . قدرت هذه الدراسة الجرعة الإشعاعية لمرضى الأطفال 51 في مركز الطبي الحديث من خلال الخضوع ل GE Optima CT 250 series – 16 slice

نتيجة هذه الدراسة تعني ان نموذج الإنحدار الخطي بين $CTDI_{vol}$ و SSDE هو

$$SSDE = -0.002+0.93(CTDI_{vol})$$

والجرعة الفعالة وهي الوسط الحسابي ± الإنحراف المعياري هو 49.69 msv ± 29.82 msv مقارنة بالمستوى الكوري الذي يبلغ 1.5 msv ± 0.2 msv وهو مرتفع .

هذه الدراسة تختتم إن الأرتفاع في الجرعة الفعالة نتيجة لعدم إستخدم برتكول الأطفال .

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List of Abbreviation

CT	Computed Tomography
ALARA	As Low As Reasonably Achievable
ICRP	International Commission on Radiological Protection
ICRU	International Commission on Radiation Units and Measurements
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation Sources and Effects of Ionizing Radiation
AAPM	American Association of Physicists in Medicine
DRL	Dose Reverence Level
CTDI	Computed Tomography dose index
$CTDI_{100}$	Computed Tomography dose index, for a100 mm length pencil ion chamber
$CTDI_{vol}$	Volumetric Computed Tomography dose index
$CTDI_{w}$	Weighted Computed Tomography dose index
DLP	Dose Length Product
SSDE	Size Specific Dose Estimation
E	Effective Dose
W_T	Tissue Weighting Factor
H_T	Equivalent dose
Kv_p	Kilo Voltage Peak
mAs	Mille Ampere Second
mSv	Mille Sievert
SD	Standard Deviation

CHAPTER ONE

Introduction

1.1 Introduction:

The purpose from radiation protection it reaches to highest level for prevention and safety from ionizing radiation for public and environment and to achievable that, by applying the recommendations of the ICRP it main objectives of radiation protection is prevention of deterministic effect and limiting the probability of stochastic effect.

Medical exposure is considering major source for man-made exposure to ionizing radiation about 96% for all man-made exposure to radiation. (UNSCEAR, 2008)

Uses of ionizing radiation in medical exposure should be justify and optimize according to recommendation of International Commission on Radiological Protection ICRP.

Ionizing radiation is radiation has ability to break tightly bound electrons from valance orbit by enough energy, in order to become charged or ionized atom.

When deposited amount of energy in unit mass of matter from ionizing radiation causes radiation doses. (ICRP, 2007)

Computed tomography (CT) is devise utilizing ionizing radiation to medical procedure and it associated with substantially higher radiation exposure than conventional radiography.

‘’Optimization means keeping the dose “as low as reasonably achievable (ALARA), economic and social factors being taken into account” (ICRP 60). ‘’For diagnostic medical exposures this is interpreted as being as low a dose as possible which is consistent with the required image quality and necessary for obtaining the desired diagnostic information.’’

The diagnostic reference level (DRL) is the core of optimization. (Frigren, 1999)

Pediatrics CT_s has more risk of developing a radiation to hereditary changes or cancer induction than adults, in order to had greater cell proliferation rate and increased opportunity for delay cancer effect.

The estimates of risk coefficient according to ICRP for population are 5% and 1.3% Sv^{-1} for cancer and hereditary effect, and for children they are 13% and 4% Sv^{-1} also. (ICRP, 2007)

Pediatric radiology is played major challenge for medical staff cause fallow different instructions for the same projection. (Alzen and Benz-Bohm, 2011)

1.2 Problem:

The risk lifetime per dose increased for pediatrics cause cell proliferation rate is high and radiographic procedure causes radiogenic risk of cancer so we wonder for estimate the effective dose to pediatric patients during CT brain to protect him from ionizing radiation according to ICRP recommendation

1.3 Objective:

1.3.1 General objective:

Estimation of radiation effective dose to pediatric CT_s for brain scan

1.3.2 Specific objective:

- The aimed of this study is reaching the pediatric CT_s to high levels for safety and protection from radiation according to the principle of ICRP, and it is justification, optimization and limitation of dose.
- The aimed of this study are estimate the effective dose, DLP, $CTDI_{vol}$, SSDE and Regress with data of pediatric patients during CT for brain and then compare the present study with international recommendation DRL_s

1.4 Thesis Layout:

These thesis content five chapters, chapter one show introduction ,objective, problem of study and thesis layout .chapter two show the literature review, theory of study and previous of study .chapter three show methodology of study. Chapter four transacts presentation result for this study chapter five including discussion, conclusion and recommendation.

CHAPTER TWO

Theoretical background and previous studies

2.1 Theoretical background:

2.1.1 Electromagnetics Wave:

It is energy as waves or streams of particles it's always around us in the form of x-rays, gamma and cosmic ray, and they are called ionizing radiation which distinguished by higher frequency and shorter wave length, in other hand there are ultra-violate, visible light, infra- red, micro waves and radio which distinguished by lower frequency and longer wavelength. (CNSC, 2012)

All matter in this world being with atoms which are consist nucleus made up of protons are positively charged and neutrons do not have charge ,and all this particles are kept together by nuclear forces. The electrons which are negatively charged moved in orbits around of nucleus. The electron negative charge attracted to nucleus positive charge by electrical forces. (CNSC, 2012)

Ionizing radiation and non- ionizing radiation are types of radiation depend on ability of energy pass through the atoms and knocks the electrons/protons from the orbits, non-ionizing radiation do not possess enough energy knocks electrons/protons but ionizing radiation they have this energy to upsetting electron/proton balance and atoms became ions. Ionizing radiation comes in form natural and man-med radioactive material. (CNSC, 2012)

2.1.2 Types of Ionizing Radiation:

2.1.2.1 Heavy charged particle:

<u>2.1.2.1.1 Alpha particles (α)</u>

Consist of two protons and two neutrons which have double positive charge. Specified relatively large mass and charge stopped by piece of paper or tissue. Useful in nuclear substances are taken into body which is radiation alpha completely absorbed in bodily tissues as radon-222 decay to polonium-218. (CNSC, 2012)

2.1.2.1.2 Beta particles (β)

Consist of partials ejected from atoms are physically identical to electrons. Specified very small can penetrate more deeply than alpha stopped by sheet of plastic, metal or glass. Has ability to penetrate to deeper in tissues and organs in the bodies, as tritium (hydrogen-3) decay to helium-3. (CNSC, 2012)

2.1.2.2 Light charged particle:

Gamma consist of photons that originate from within nucleus and x- ray consist of photon that originate from outside the nucleus and have energy lower than gamma radiation. Specified can travel much greater distance than alpha or beta particles. Has ability to penetrate tissues and organs in the bodies even those source radiation outside the body. As Cobalt-60 which decay to nickel-60. (CNSC, 2012)

2.1.2.3 Neutron particles (N):

Founded in natural source when have spontaneous fission as a part of cosmic ray and man-made source as nuclear reactor. Have ability to penetrate tissues and organs when radiation source outside the body. Can stopped or shielded by material contain hydrogen such as paraffin wax and plastic. (CNSC, 2012)

2.1.3 CT:

Ionizing radiation is playing significant role in diagnostic procedure which is depending on atomic number of tissue such as computed tomography

2.1.3.1 CT Physical principles:

Computed tomography is imaging modality for evaluation of anatomical structure. X-ray tube and detectors rotate and synchronal with narrow beam around the patient, A collimated x-ray beam is directed from the patient's head to toe, and the attenuated image-forming x-radiation is measured by a detectors measures average linear attenuation coefficient μ, between the tube and detectors, it represent the intensity of X- ray reduced by material passed through it and summed up from multiple of angles used in a process called reconstruction. After the signal from the detector is analyzed, the computer reconstructs the image and displays the image on a monitor. Computer reconstruction of the cross-sectional anatomy is accomplished with mathematical equations (algorithms) adapted for computer processing. (Bushong, S.C., 2013)

2.1.3.2 CT Radiation dose quantities:

Radiation passed through air that is do exposure. The ICRU defines **Exposure X** as: X = dQ/dm , where dQ is the absolute value of the total charges of **ions of one sign** produced **in air**, when all the electrons (+ or -) **liberated by photons** in air of mass dm, are completely stopped in air.

The SI unit is C/kg, special unit used, the Rontgen "R

One $R = 2.58 \times 10^{-4}\ C/kg$

When the radiation or energy interact with body that is lead to health detriment so biological effect of energy deposition determined by Effective dose E (unit: mille Sievert (mSv)) according to ICRP 60 is defined as is the sum over all the organs and tissues of the body of the product of the equivalent dose, H_T, to the organ or tissue and a tissue weighting factor, W_T, for that organ or tissue:

$$E = \sum_{T} W_T H_T$$

Unit: Sievert (Sv)

The tissue weighting factor, W_T, for organ T represents the relative contribution of that organ to the total detriment arising from stochastic effects for uniform irradiation of the whole body. (ICRP, 1991)

1 Gray (SI unit) = 100 rad

1 Sievert (SI unit) = 100 rem

1 R ≈ 1 rad ≈ 1 rem (for X-ray)

2.1.3.3 CT dose descriptors:

“The dose quantities used in projection radiography are not applicable to CT for three reasons:

The dose distribution inside the patient is completely different from that for a conventional radiogram, where the dose decreases continuously from the entrance of the X-ray beam to its exit, with a ratio of between 100 and 1000 to 1,the scanning procedure using narrow beams along the longitudinal z-axis of the patient implies that a significant portion of the radiation energy is deposited outside the nominal beam width and the situation in CT is further complicated by the circumstances in which - unlike in conventional projection radiography - the volume to be imaged is not irradiated simultaneously.” (Nagel, Hans, 2007)

The main CT dose descriptors is Computed Tomography Dose Index (CTDI) which is measure of local dose when distribution in the axis –z of rotation for the scanner (unit: mille gray (mGy)) .to estimates the dose for organs used standard dosimetry phantoms which are 32 cm in diameter PPMA (PPMA is the type of cylindrical Perspex that makes up this phantom) for trunk region of adult and 16 cm diameter for head examination and also used for dose assessment in pediatric examinations. (Nagel, Hans, 2007)

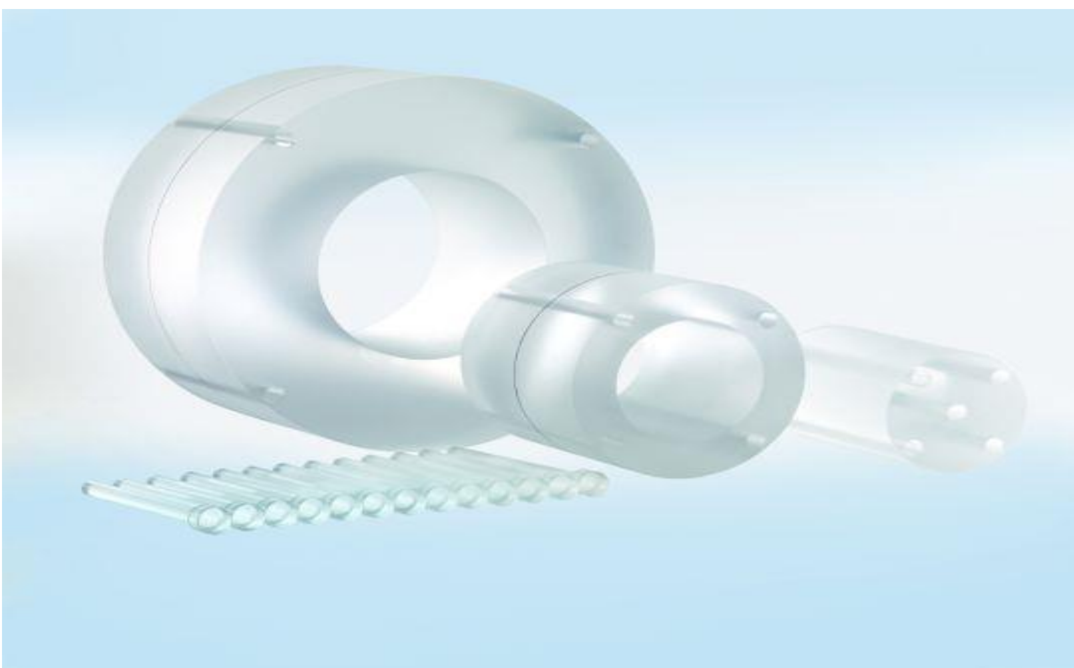

Fig 2.1 Cylindrical standard CT dosimetry phantoms (16 and 32 cm in diameter) made from Perspex for representative measurements of CTDI in regions of the head and the trunk

Fig 2.2 Ionization Chamber DCT10 for DLP (in mGy*cm) and CTDI measurements at CT scanner

“Each pair of CTDI values (central and peripheral) can be combined into one single one named ‘Weighted CTDI ($CTDI_w$)’, which represents the CTDI averaged over the cross section of the pertaining phantom

$$CTDI_w = 1/3 * CTDI_{XYZ,center} + 2/3 * CTDI_{XYZ,peripheral}$$

where the subscript XYZ stands either for Head or Body. In daily practice, $CTDI_w$ is used as one of two dose descriptors for dose recommendations (‘reference values’) that have been introduced by the European Commission (1999a)”. (Nagel, Hans, 2007)

When dose displayed reference values of $CTDI_w$ used ‘volume CTDI ($CTDI_{vol}$)’ for camprison and the CTDIvol displayed is used to assess pediatric radiation exposure

$CTDI_{vol} = CTDI_w / Pitch$

“Pitch is defined as the ratio of table travel per 360º rotation (I) to the beam width (N*T)

Pitch = I / (N*T)

N ≡ number of active detector channels

T ≡ channel width

- Pitch of 0.5 results in doubling the CT dose
- Pitch of 2.0 results in half the CT dose

The dose length product (DLP) is multiplying the total scan length traveled (in cm) by the $CTDI_{volume}$ (in mGy)”. (Sven Gallo M.Sc., CRE, RSO, 2012)

Finally effective dose, it allow comparison with radiation exposures from projection radiography than CTDI and DLP

The Effective Dose (mSv) converted by multiplying the DLP with a k-factor

Effective Dose = DLP * k   (Sven Gallo M.Sc., CRE, RSO, 2012)

Table 2.1 where k is a body part and age specific conversion factor

Region of body	$K(mSv\ mGy^{-1}\ cm^{-1})$				
	0 year old	**1 year old**	**5 year old**	**10 year old**	**Adult**
Head and neck	0.013	0.085	0.0057	0.0042	0.0031
Head	0.011	0.067	0.0040	0.0032	0.0021
Neck	0.017	0.012	0.011	0.0079	0.0059
Chest	0.039	0.026	0.018	0.013	0.014
abdomen≈&pelvis	0.049	0.030	0.020	0.015	0.015
Trunk	0.044	0.028	0.019	0.014	0.015

2.1.3.4 Size Specific Dose Estimation (SSDE) in pediatric and adult body CT examination:

According to AAPM 204 "Is defined as a patient dose estimate which takes into consideration corrections based on the size of the patient, using linear dimensions measured on the patient or patient images".

SSDE patient or phantom = $CTDI_{vol}^{16\text{ or }32} \times f_{size}^{16\text{ or }32}$

Were f_{size} coefficient conversion factor to scale volume computed tomography dose index ($CTDI_{vol}$) values calculated using either a 16 or 32 cm diameter CTDI patient or phantom. (AAPM, 2015)

2.2 Previous Studies:

The number of publications on radiation exposure in CT for improve management and optimization seen a yearly increases with growing concern about protection issues. Currently no system found to track patient's lifetime cumulative dose from medical sources.

(Brody, A.S., Frush, D.P., Huda, W. and Brent, R.L., 2007) were reported Radiation Risk to Children from Computed Tomography "Imaging studies that use ionizing radiation are an essential tool for the evaluation of many disorders of childhood. Ionizing radiation is used in radiography, fluoroscopy, angiography, and computed tomography scanning. Computed tomography is of particular interest because of its relatively high radiation dose and wide use. Consensus statements on radiation risk suggest that it is reasonable to act on the assumption that low-level radiation may have a small risk of causing cancer. The medical community should seek ways to decrease radiation exposure by using radiation doses as low as reasonably achievable and by performing these studies only when necessary. There is wide agreement that the benefits of an indicated computed tomography scan far outweigh the risks. Pediatric health care professionals' roles in the use of computed tomography on children include deciding when a computed tomography scan is necessary and discussing the risk with patients and families. Radiologists should be a source of consultation when forming imaging strategies and should create specific protocols with scanning techniques optimized for pediatric patients. Families and patients should be encouraged to ask questions about the risks and benefits of computed tomography scanning. The information in this report is provided to aid in decision-making and discussions with the health care team, patients, and families."

(Brenner, D.J., Elliston, C.D., Hall, E.J. and Berdon, W.E., 2001)Were reported Estimated Risks of Radiation-Induced Fatal Cancer from Pediatric CT "The larger doses and increased lifetime radiation risks in children produce a sharp increase, relative to adults, in estimated risk from CT. Estimated lifetime cancer mortality risks attributable to the radiation exposure from a CT in a 1-year-old are 0.18% (abdominal) and 0.07% (head)—an order of magnitude higher than for adults—although those figures still represent a small increase in cancer mortality over the natrual background rate. In the United States, of approximately 600,000 abdominal and head CT examinations annually performed in children under the age of 15 years, a rough estimate is that 500 of these individuals might ultimately die from cancer attributable to the CT radiation."

(Smith-Bindman, R., Lipson, J., Marcus, R., Kim, K.P., Mahesh, M., Gould, R., De González, A.B. and Miglioretti, D.L., 2009) Were reported Radiation dose associated with common computed tomography examinations and the associated lifetime attributable risk of cancer "Radiation doses varied significantly between the different types of CT studies. The overall median effective doses ranged from 2 mille sieverts (mSv) for a routine head CT scan to 31 mSv for a multiphase abdomen and pelvis CT scan. Within each type of CT study, effective dose varied significantly within and across institutions, with a mean 13-fold variation between the highest and lowest dose for each study type. The estimated number of CT scans that will lead to the development of a cancer varied widely depending on the specific type of CT examination and the patient's age and sex. An estimated 1 in 270 women who underwent CT coronary angiography at age 40 years will develop cancer from that CT scan (1 in 600 men), compared with an estimated 1 in 8100 women who had a routine head CT scan at the same age (1 in 11 080 men). For 20-year-old patients, the risks were approximately doubled, and for 60-year-old patients, they were approximately 50% lower."

CHAPTER THREE

Materials and Method

The aimed of this study is estimation of radiation dose to pediatrics by uses brain CT scan in Modern Medical center from 23/9 to 19/11 -2018

3.1 Materials:

- CT manufacture GE , model Optima CT 520 series, detector type (slice) 16, and Installation date 2017
- Group of pediatric (51) patients, 30 Male and 21 Female

3.2 Methods:

- Data were collected using a sheet and designed to evaluate the patient dose and radiation related factor. This data included age and gender; in addition CT console parameter (KV_p- peak tube potential, mean mAs- tube current with constant time , $CTDI_{vol}$ - volume CT dose index, DLP - dose length product, Type of scout, Image slice thickness and Number of image slice thickness).

- used Effective dose equation to measuring pediatric dose from CT scanners, and it is:

$$\text{Effective Dose (mSv)} = K*DLP$$

Were k is a body part and age specific conversion factor

- used Size-specific dose estimate (SSDE) to measuring pediatric dose from CT scanners, and it is:

$$\text{SSDE patient or phantom} = CTDI_{vol}^{16\text{ or }32} \times f_{size}^{\ 16\text{ or }32}$$

Were f_{size} coefficient conversion factor to scale volume computed tomography dose index ($CTDI_{vol}$) values calculated using either a 16 or 32 cm diameter CTDI patient or phantom

- The data analyzed by using software computer system (SPSS)

CHAPTER FOUR

Result

Table shows the relation of age group with mAS, Kv_p, $CTDI_{vol}$, DLP and ED, and regress SSDE on $CTDI_{vol}$

Table 4.1 show CT mAS for different age group

Age group	Mean	Max	Min	SD
<1 _ 5	151.2179	185	144.62	7.166351
6 _ 10	164.2	260	149	35.61352
11 _ 15	159.8125	195.43	149.38	12.8627

Table 4.2 show CT Kv_p for different age group

Age group	Mean	Max	Min	SD
<1 _ 5	120.69	140	120	3.713907
6 _ 10	120	120	120	0
11 _ 15	120	120	120	0

Table 4.3 show CT $CTDI_{vol}$ for different age group

Age group	Mean	Max	Min	SD
<1 _ 5	46.5304	96.61	26.3	18.71474
6 _ 10	49.017	99.78	36.03	21.33233
11 _ 15	41.09833	50.86	37.53	3.431901

Table 4.4 show CT DLP for different age group

Age group	Mean	Max	Min	SD
<1 _ 5	651.7979	1452.58	371.5	279.3697
6 _ 10	851.759	2930.74	466.27	750.9665
11 _ 15	610.7508	712.05	550.05	59.24383

Table 4.5 show CT ED for different age group

Age group	Mean	Max	Min	SD
<1 _ 5	28.30069	97.32	2.49	27.33304
6 _ 10	3.175	9.38	1.87	2.288237
11 _ 15	18.21	2.28	1.76	0.194848

Table 4.6 show model summary of Linear Regress SSDE on $CTDI_{vol}$

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	1.000 a	1	1	0.00231

a. Predictors: (Constant), $CTDI_{vol}$

Table 4.7 show ANOVA of Linear Regress SSDE on $CTDI_{vol}$

Model		Sum of Squares	DF	Mean Square	F	Sig.
1	Regression	12446.366	1	12446.366	2.34E+09	.000a
	Residual	0	49	0		
	Total	12446.366	50			

Table 4.8 show Coefficient (a) of Linear Regress SSDE on $CTDI_{vol}$

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.002-	0.001		-2.643-	0.011
	CTDIvol	0.93	0	1	4.83E+04	0

SSDE is dependent variable.
CTDIvol is independent variable.

CHAPTER FIVE

Discussion, Recommendation and Conclusion

5.1 Discussion:

The study show variation of mAs and $CTDI_{vol}$ with age group in table 4.1 and table 4.3 attributed to several factors such as patient size and machine performance. In table 4.2 the Kv_p constant with age group. Finally the table 4.5 and table 4.4 of Effective Dose and Dose Length Product were not show straight line relationship.

In other hand, the study showed the Linear Regress SSDE on $CTDI_{vol}$ in table 4.6 which contained R Value represents simple correlation and Is 1 with indicate a high degree of correlation.$R^{\wedge 2}$ Value indicates how much of total variation in the dependent variable SSDE, can be explained by the independent variable SSDE in this case, 100% can be explained which is very large. In table 4.7 show ANOVA of Linear Regress SSDE on $CTDI_{vol}$, Sig. is less than 0.05 that mean significantly predicts the CTDIvol variable (it is good fit for the data).Finally the table 4.8 show Coefficients(a) of Linear Regress SSDE on $CTDI_{vol}$

Linear Regression equation between $CTDI_{vol}$ and SSDE which is

$SSDE = -0.002+0.93(CTDI_{vol})$.

Also the result of this study the mean ± SD for Effective Dose it's 49.69 msv ± 29.82 msv comparing with Korean standard which is 1.5 msv ± 0.2 msv it's highest referring to used factor of adult as kv_p, mAs and scan rang.

5.2 Conclusion

The study concludes to the dose is highest comparing with Korean standard referring to not used pediatric protocol.

5.3 Recommendations

- Recommend the result of this study a great need for a nation-wide evaluation and investigation of optimization of procedures in radiological examinations.
- Must establishing a national dosimetry protocol and reference dose level in the country.
- Must training of staff in radiation protection concept.

5.4 Appendix

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Data sheet for estimation of radiation dose to pediatric patient during CT for brain scan

Hospital……………………………………………..

Manufacture……………………………………Installation date…………………………………………………..

Model……………………………………………….. Detector type (slice)…………………………………………..

Patient No.	Gender	Age	Type of Scout	KV_p	Mean mAs	Slice thickness	No. slice thickness	DLP mGy*cm	$CTDI_{vol}$ mGy	Date

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