Dosimetric Evaluation for Eye Lens and Thyroid Gland from Brain Computed Tomography Scan

Prepeard By: Haya Jamal Alruzieh

Supervisor: Dr.Ali Abu Arra

A Thesis Submitted in Partial of Requirements for the Bachelor's Degree of Medical Imaging.

An-Najah National University

January 2022

ACKNOWLEDGEMENT

May Allah, the Founder of the world, have mercy on us all. Special thanks are given to Dr. Ali Abu Arra for his sponsorship of my studies, for his endurance and inspiration. Also, I would like to send special thanks to my dear teachers, Prof. Abed Al-Nasser Assi and Dr. Jihad Ahmad Alshanti who dedicated themselves to teaching and sharing all their knowledge.

Endless sincere gratitude to my family, to my mother who was always by my side and was my biggest supporter, for my father's soul who struggled to provide the best education and life for me -may Allah rest his soul in peace- , and my brothers and sisters who believed in my dream and gave me strength every day.

I would like to thank my dear friends who have been with me all the time, especially Roaa Barabrah for her assistance. I am very much thankful to my lovely childhood friends in Saudi Arabia who have always been there for me and supported me. Finally, I would like to express my appreciation to Mr.Samir Awrtani for his assistance during my educational career.

Haya Alruzieh

Table of Content

	Page
ACKNOWLEDGEMENT	II
Table of Content	III
List of Figures	VIII
List of Tables	IX
List of Equations	X
List of Abbreviations	XI
الملخص	XIII
ABSTRACT (English)	XIV
CHAPTER ONE: INTRODUCTION	1
1.1 Introduction	1
1.2 Problem Statement	4
1.3 Research Objective	5
CHAPTER TWO: BACKGROUND AND THEORY	6
2.1 Background and Theory	6
2.1.1 CT Component	6

2.1.2 CT Physics 8

2.1.3 CT Scan Modes 11

2.1.3.a Step and Shoot Scanning 11

2.1.3.b Helical (Spiral) Scanning 11

2.1.4 Fundamentals of Radiation Dosimetry 12

2.1.4.a Exposure 12

2.1.4.b Absorbed Dose 13

2.1.4.c Equivalent Dose 13

2.1.4.d Effective Dose 14

2.1.5 CT Dosimetry 15

2.1.5.a Computed Tomography Dose Index (CTDI) 16

2.1.5.b Dose Length Product (DLP) 16

2.1.6 Factors Affecting Dose in CT Scan 18

2.1.6.a Tube Current 18

2.1.6.b Kilovoltage Peak 19

2.1.6.c Collimation 19

2.1.6.d Filtration 19

2.1.6.e Pitch 20

2.1.7 Radiation Biological Effects 21

2.1.7.a Stochastic Effects 21

2.1.7.b Deterministic Effects 21

2.1.8 Anatomy 22

2.1.8.a Head Anatomy 22

2.1.8.b Neck Anatomy 23

2.2 Previous study 25

CHAPTER THREE: METHOD AND MATERIALS 27

3.1 Study Design 27

3.2 Study Population 27

3.3 Image Acquisition and Reconstruction 28

3.4 Data Collection 29

3.5 Radiation Dose Calculation 29

3.5.1 Acquisition Length 29

3.5.2 Effective Dose Calculation 29

3.5.2.a Method 1: Using DLP and k Coefficients from the ICRP 103 29

3.5.2.b Method 2: ED and Organ Dose Estimation Using VirtualDose™ CT Software 30

3.5.2.c Organ Dose 31

3.5.2.d Cancer Risk Assessment 31

CHAPTER FOUR: RESULT AND DISCUSSION 32

4.1 Study Population 32

4.2 Effective Dose 33

4.2.1 Method One: ED_{DLP} 33

4.2.2 Method Two: ED VirtualDose™ CT Software 34

4.2.3 Comparison of Effective Dose Calculation Methods 34

4.3 Organ Equivalent Doses 36

4.4 Cancer Probability 37

4.5 Discssion 39

4.5.1 Comparison With Other Study 43

CHAPTER FIVE: CONCLUSION 45

5.1 Conclusion 45

5.2 Limitation 46

5.3 Recomindation 46

5.4 Future Studies 47

REFERENCES 48

APPENDICES 51

APPENDIX A 51

APPENDIX B 52

APPENDIX C 53

List of Figures

		Page
Fig. 2.1	The external and internal appearance of a CT scanner, showing the gantry houses imaging components, the gantry aperture, and the patient table.	7
Fig.2.2	A CT scanner shows the main components and the basic principle of the way a CT scanner works.	9
Fig. 2.3	The relationship between CT number and brightness level.	10
Fig 2.4	Comparison of conventional/axial (A), and spiral/helical (B) CT scanning sequences.	12
Fig 2.5	Relationship among tube voltage, tube current-time product, CT dose index-volume weighted, scan length, dose length product (DLP), and effective dose.	17
Fig 2.6	The gantry moves along the z-axis plane (arrow) if the Pitch >1that will create gaps in the resulting image slices from each gantry rotation. A pitch of 1 creates no gaps and no overlap and a pitch of <1 creates slice data overlap.	20
Fig 2.7	The biconvex shape of the lens is seen, and the cellular structure of the lens.	23
Fig 2.8	Anterior and posterior view for thyroid anatomy.	24
Fig 3.1	Philips Brilliance CT 64 slice	28
Fig 4.1	The average value of ED_{DLP} compared to $ED_{Virtual}$ in both helical and axial scanning	34
Fig 4.2	The average value of ED_{DLP} compared to $ED_{Virtual}$ in helical scan mode	35
Fig 4.3	The average value of ED_{DLP} compared to $ED_{Virtual}$ axial scan mode.	35
Fig. 4.4	The average value of organ equivalent dose for helical scan by gender.	36
Fig. 4.5	The average value of Organ Equivalent Dose For Axial Scan by gender.	37
Fig 4.6	The average value of cancer risk assessment of thyroid by age group, gender for the helical scan.	38
Fig 4.7	The average value of cancer risk assessment of thyroid by age group, gender for the axial scan.	38

List of Tables

		Page
Table 2.1	ICRP recommended Radiation Weighting Factors W_R, for different radiation types.	14
Table 2.2	The tissue weighting factors according to the actual determination of the ICRP the risk factors.	15
Table 3.1	Exposure-related parameters for axial and helical scanning.	28
Table 4.1	Demographic data for the entire population and patient age-related sub-cohort for helical and axial scan modes.	32
Table 4.2	The mean ED_{DLP} based on gender for helical scan	33
Table 4.3	The mean ED_{DLP} based on gender for axial scan	33
Table 4.4	Comparesim between the mean thyroid and lens equivalent dose received in this research according to VirtualDose^{TM} software and other studies	44

List of Equations

	Page
Equation 1	13
Equation 2	14
Equation 3	16
Equation 4	16
Equation 5	16
Equation 6	29
Equation 7	30
Equation 8	30
Equation 9	31

List of Abbreviations

3D	Three Dimensions
ADC	Analog to Digital Convetor
AEC	Automated Exposure Control
ALARA	As Low As Reasonably Achievable
ATCM	Automatic Tube Current Modulation
C/kg	Coulomb per kilogram
C1-C7	First to Seven Cervical Vertebrae
C5-T1	Fifth cervical vertebra to first thoracic vertebra
CAT	Computed Axial Tomography
CT	Computed Tomography
$CTDI_{VOL}$	CT Dose Index- volume
$CTDI_{W}$	CT Dose Index- weighted
D	Absorbed dose
DLP	Dose Length Product
ED	Effective dose
Gy	Gray
H	Equivalent Dose
HU	Hounsfield Unit
ICRP	International Commission on Radiological Protection
J/kg	Joule per Kilogram
K	Conversion Coefficient
kVp	Peak Voltage

mA	Milliampere
mAs	milliampere-second
MDCT	Multi-Detector Computed Tomography
PACS	Picture Archiving And Communication System
R	Roentgen
rad	Radiation Absorbed Dose
RDSR	Radiation Dose Structured Report
rem	Radiation Equivalent Man
Saas	Software as a Service
SI	International System of Units
Sv	Sievert
T3-T4	Third to Fourth Thorasic Vertebra
W_R	Radiation Weighting Factor
W_T	Tissue Weighting Factor
μ	linear Attenuation Coefficients

تقييم الجرعات الإشعاعية لعدسة العين والغدة الدرقية من فحص التصوير المقطعي المحوسب للدماغ

الملخص

يعد التصوير المقطعي للدماغ من أحد أكثر الفحوصات شيوعًا في السنوات الأخيرة. تهدف هذه الدراسة إلى تقدير الجرعة الفعالة (ED) وجرعة الأعضاء من التصوير المقطعي للدماغ ، واحتمالية إصابة الغدة الدرقية بالسرطان نتيجة التعرض للإشعاع، لتحقيق هدف هذه الدراسة، تم تقدير الجرعة باستخدام الحساب اليدوي وبرنامج VirtualDoseTM القائم على مونت كارلو والمتوفر تجاريًا .

تم اختيار80 مريضاً بالغاً عشوائياً من كلا الجنسين من مستشفى الشهيد ثابت ثابت.حيث تم تطبيق أوضاع المسح الحلزونية والمحورية للدماغ. تم تسجيل البيانات الديموغرافية للمرضى ، ومعلّمات المسح ، ومؤشرات الجرعة التي تتضمن كيلوفولتاج أنبوب الأشعة السينية (kVp) ، ملي أمبير في الثانية (ملي أمبير) ، منتج طول الجرعة (DLP) ، حجم مؤشر جرعة التصوير المقطعي المحوسب(CTDIvol) .

أظهرت الدراسة أن متوسط قيمة الحساب اليدوي هو 1.8 ملي سيفرت مقارنة بمتوسط قيمة الجرعة الفعالة باستخدام VirtualDoseTM 5.0ملي سيفرت للمسح الحلزوني. بينما في الفحص المحوري ، يبلغ متوسط قيمة الحساب اليدوي 2.4 ملي سيفرت مقارنة بمتوسط قيمة 4.1 VirtualDoseTM ملي سيفرت.

بالنسبة للمسح الحلزوني ، كانت أعلى قيمة محسوبة 2.1 ملي سيفرت ، تنتمي إلى إنثى تبلغ من العمر 82 عامًا. أما المسح المحوري ، كانت أعلى قيمة للجرعة الفعالة محسوبة 2.9 ملي سيفرت ، لأنثى في سن 55 عامًا. استنادًا إلى برامجVirtualDoseTM ، في المسح الحلزوني ، أعلى قيمة هي 6.5 ملي سيفرت ، لأنثى تبلغ من العمر 81 عامًا. من ناحية أخرى ، في المسح المحوري ، كانت أعلى قيمة 8.3 ملي سيفرت تخص أنثى تبلغ من العمر 55 عامًا.

كان متوسط قيم جرعات الأعضاء في جميع المرضى 43.1 و 19.7 ملي جراي للغدة الدرقية وعدسة العين ، على التوالي في المسح الحلزوني. بينما كان المسح المحوري 9.1 ملي جراي للغدة الدرقية ، و 32.1 ملي جراي لعدسة العين. أعلى قيمة في تقدير احتمالية الإصابة بسرطان الغده الدرقية للمسح الحلزوني هي 106× 2.3 عند الإناث البالغات من العمر 20 ، 68 عامًا. أيضاً، أعلى قيمة للمسح المحوري 106 ×2.7 لأنثى تبلغ من العمر 55 سنة.

بشكل عام، جرعات الإشعاع المحسوبة من فحوصات التصوير المقطعي المحوسب للدماغ في هذه الدراسة ضئيلة ومماثلة لتلك الجرعات الموصوفة في الأعمال الأخرى، ومع ذلك يجب على فني الأشعة اختيار وتعديل البروتوكولات لتجنب الإشعاع غير الضروري للمرضى وتلبية مبدأ أدنى مستوى يمكن تحقيقه بشكل معقول (ALARA).

Dosimetric Evaluation for Eye Lens and Thyroid Gland from Brain Computed Tomography Scan

ABSTRACT

Brain Computed Tomography scan is one of the most frequent examinations in the last years. This study was aim to estimate the effective dose (ED) and the organ doses from brain computed tomography (CT) scan, and cancer probability was for the thyroid gland.

The manual calculation and commercially available Monte Carlo-based software VirtualDose^{TM} CT were used to achieve the objective of this study. A total of 80 adult patients from both genders were selected randomly from the Thabet-Thabet hospital. Helical and axial scan modes were applied. Demographic data for patients, scanning parameters, and dose indicators that involve the x-ray tube kilovoltage (kVp), milliampere-second (mAs), dose length product (DLP), computed tomography dose index volume ($CTDI_{vol}$) were recorded.

The average value of ED_{DLP} is 1.8 mSv compared to $ED_{Virtual}$ with an average value of 5.0 mSv for the helical scan. In an axial scan, the average value of ED_{DLP} is 2.4 mSv compared to $ED_{Virtual}$ with an average value of 4.1 mSv. For Helical Scan, the highest calculated ED value was 2.1 mSv, belonging to females aged 82 years. For Axial Scan, the highest calculated ED value was 2.9 mSv, belonging to females aged 55 years old.

Based on virtual software, in the helical scan mode, the highest value is 6.5 mSv, belonging to a female who is 81 years old. On the other hand, in the axial scan, the highest value was 8.3 mSv belonging to a female who is 55 years old.

The average values of organ doses in the whole population were 43.1 and 19.7 mGy for the thyroid gland and eye lens, respectively in helical Scan. While axial scan was 9.1 mGy for thyroid, and 32.1mGy for eye lens. The highest value in thyroid cancer risk assessment is 2.3×10^{6} found in 2 females who are 20, 68 years old in the helical scan. Also, for the axial scan, the highest value is 2.7×10^{6} belonging to a female who is 55 years old. Generally, the calculated radiation doses from the brain CT exams in this study are minimal and similar to those described in other works of literature, however, the technologist should choose and adjust protocols to avoid unnecessary radiation to patients and satisfy the as low as reasonably achievable (ALARA) principle.

Keywords: CT, Organ dose, Effective dose, Radiation cancer risk.