RADIATION DOSE REDUCTION IN ADULT ABDOMEN AND PELVIS CT SCAN

By

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To

My husband;
Dr. Razul Md Nazri Md Kasim

My daughter;
Hurin Nashwa

Thank you for the love, support and patience.

To

My parents and my siblings;

Thank you for the prayers and being there through my happy and difficult moment.

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ABSTRAK

BAHASA MALAYSIA

Tajuk:

Penurunan dos radiasi ke atas pesakit dewasa yang menjalani CT scan abdomen dan pelvis.

Latar belakang:

CT scan merupakan alat yang penting dalam pemeriksaan radiologi kerana ia memberikan maklumat berkenaan anatomi dalaman manusia. Berdasarkan kemajuan teknologi skaner terkini, jumlah pemeriksaan CT scan akan sentiasa meningkat. Antara semua pemeriksaan CT scan, bahagian abdomen dan pelvis mempunyai dos efektif paling tinggi berbanding bahagian badan yang lain. Oleh itu adalah penting untuk menurunkan dos radiasi ke tahap minimum dengan mengubah parameter skan. Faktor teknikal yang mempengaruhi dos radiasi daripada skan termasuk tiub voltan, 'tube current' (mAs), masa skan, 'pitch', ketebalan hirisan (slice thickness) dan isipadu scan (scanning volume). Dalam kajian ini hanya 'tube current' (mAs) akan diubah ke tahap minimum manakala faktor lain dikekalkan seperti protokol CT scan biasa.

Tujuan:

Kajian ini bertujuan untuk menilai sama ada penurunan dos radiasi ke atas CT scan abdomen dan pelvis bagi pesakit dewasa dengan menurunkan mAs dapat menghasilkan imej yang mempunyai kualiti diagnostik.

Metodologi:

Ini merupakan kajian keratan rentas secara rawak. Butiran data tentang umur, jantina dan ukuran dimensi abdomen direkodkan daripada 82 orang pesakit dewasa yang menjalani pemeriksaan CT scan abdomen dan pelvis berkontras daripada bulan April 2008 hingga Oktober 2008. 41 pesakit menggunakan 240 mAs (kumpulan kawalan), manakala 41 lagi pesakit menggunakan 180 mAs (kumpulan kajian-25% penurunan dos radiasi). Keperincian anatomi, kualiti imej dan tahap keyakinan dalam mencapai diagnosis dikelaskan pada skala 1 (tidak memuaskan) hingga 4 (sangat memuaskan).

Keputusan:

Tiada perbezaan signifikan ($p=0.14$) dalam imej kualiti di antara kumpulan kajian (180mAs-25% penurunan dos radiasi) dan kumpulan kawalan (240 mAs). Tidak terdapat perbezaan signifikan ($p=0.2$) dalam imej kualiti di antara pesakit yang mempunyai diameter < 34.5 cm dan ≥ 34.5 cm. Juga tidak terdapat perbezaan signifikan ($p=0.7$) dalam imej kualiti di antara pesakit yang mempunyai kawasan keratan rentas abdomen $<$ 800 cm^2 dan $\geq$ 800 cm^2 apabila menggunakan 180mAs.

Kesimpulan:

Penurunan dos radiasi sebanyak 25% boleh dicapai oleh pesakit dewasa yang menjalankan pemeriksaan CT scan abdomen dan pelvis dengan menggunakan 180mAs, tanpa menjejaskan kualiti diagnostik imej.

ABSTRACT

ENGLISH

Title:

Radiation dose reduction in adult abdomen and pelvis CT scan.

Background:

CT scan is an extremely valuable tool as it yields a lot of information regarding the internal human anatomy. Now with future advances in scanner technology the number of CT examination will likely continue to rise. Among all CT abdomen and pelvis have the highest effective dose. Thus it is important to minimize the dose by adjusting scanning parameter. Major technical factors that influence radiation dose from CT scan include tube voltage, tube current, scanning time, pitch, slice thickness and scanning volume. In this study only the tube current (mAs) is adjusted to as minimum as possible while the other factors are kept constant.

Objective:

The aim of this study is to determine whether a lower radiation dose could be used in adult abdomen and pelvis CT scan without affecting the diagnostic accuracy of the images.

Method:

This is a randomised cross sectional prospective trial. Age, gender and abdominal dimension were recorded from 82 adult patient who underwent contrasted abdomen and pelvis CT scan from April 2008 until October 2008. 41 patients underwent CT at 240 mAs

(control group), and 41 at 180 mAs (trial group-25% dose reduction). The anatomic details, image quality and the degree of confidence in reaching a diagnosis were graded as a scale of 1 (unsatisfactory) to 4 (excellent).

Result:

The difference in perceived image quality between the control and trial group was not statistically significant ($p=0.14$). There is no significant difference in image quality score in patient with transverse abdominal diameter <34.5 cm and ≥ 34.5 cm ($p=0.20$). There is also no significant difference in image quality score in patient with cross sectional abdominal area $< 800\ cm^2$ and $\geq 800\ cm^2$ ($p=0.72$)

Conclusion:

25% dose reduction can be achieved in adult abdomen and pelvis CT scan if performed at 180 mAs, without deterioration of diagnostic image quality.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS ii

ABSTRAK iii

BAHASA MELAYU iii

ENGLISH v

TABLE OF CONTENTS vii

LIST OF TABLES xi

LIST OF FIGURES xii

ABBREVIATIONS xiii

1.0 INTRODUCTION 1

2.0 LITERATURE REVIEW 4

2.1 Introduction to CT scan 4

2.2 CT scan equipment 5

2.3 Image quality and artifact in CT scan 8

2.3.1 image quality 8

2.3.2 CT artifact 9

2.4 Radiation Hazard 10

2.4.1 Ionizing radiation interaction with tissue 10

2.4.2 Radiation effects 14

2.5 CT scan radiation dose optimization	16
2.5.1 CT dose measurement	16
2.5.2 Strategies to reduced CT scan dose	17
3.0 OBJECTIVES	21
3.1 General objective	21
3.2 Special objectives	21
3.3 Research hypothesis	22
4.0 METHODOLOGY	23
4.1. Study design	23
4.2.Phantom study	23
4.3 Patient study	25
4.3.1 Study sample	25
4.3.2 Sample size	25
4.3.3 Inclusion criteria	25
4.3.4 Exclusion criteria	26
4.3.5 Research tools	26
4.3.6 Technique	26
4.4 Statistical Analysis	29
4.4.1 Descriptive analysis	29
4.4.2 Statistic Analysis	30

5.0 RESULT 31

5.1 Phantom study 31

5.2 Patient study 32

5.2.1 Demographic data 33

5.2.1.1 Age distribution 33

5.2.1.2 Gender distribution 34

5.2.2 Baseline characteristics of subjects 36

5.2.3 Image quality score in final evaluation and ability to reach reach conclusion in adult abdomen and pelvis CT scan 37

5.2.4 The average score and mean difference of image quality score with standard dose (mAs of 240) and 25% dose reduction (mAs of 180) 38

5.2.5 The average score and mean difference of image quality score at 25% dose reduction (mAs of 180) with transverse abdominal diameter (< 34.5 cm and ≥ 34.5 cm) 40

5.2.6 The average score and mean difference of image quality score at 25% dose reduction (mAs of 180) with cross sectional abdominal area < 800 cm^2 and ≥ 800 cm^2 42

6. 0 DISCUSSION 44

6.1 The average score and mean difference of image quality score with standard dose (mAs of 240) and 25% dose reduction (mAs of 180) 45

6.2 Average score and mean difference of image quality score at the 25% dose reduction (180 mAs) in different abdominal dimension (cross sectional area, 49 transverse and anteroposterior diameter

7.0 CONCLUSION 52
8.0 LIMITATIONS AND RECOMMENDATIONS 54
REFERENCES 58
APPENDICES 63
APPENDIX A Guidelines on Quality Criteria for CT abdomen and pelvis. 63
APPENDIX B CT Technical, clinical and physical parameters 69
APPENDIX C Data collection form 81
APPENDIX D Cross section of CTP 500 82

LIST OF TABLES

Table 2.1 : Threshold dose for deterministic effects in medical radiation exposure. 14

Table 4.1 : CT scan parameters for phantom study 23

Table 4.2 : Scanning parameter for abdomen and pelvis CT scan 26

Table 5.1 : Gender distribution of subject according to control and study group. 35

Table 5.2 : Mean value of baseline characteristics of subjects 36

Table 5.3 : Frequencies of image quality score in final evaluation and ability to reach conclusion in both groups 37

Table 5.4 : The average score and mean difference of image quality score with standard dose (mAs of 240) and 25% dose reduction (mAs of 180) 39

Table 5.5: The average score and mean difference of image quality score at 25% dose reduction (mAs of 180) with transverse abdominal diameter.($<$ 34.5 cm and $\geq$ 34.5 cm) 41

Table 5.6: The average score and mean difference of image quality score at 25% dose reduction (mAs of 180) with cross sectional abdominal area $<$ 800 cm^2 and $\geq$ 800 cm^2 43

LIST OF FIGURES

Figure 2.1 : Chain of event following exposure to ionizing radiation	12
Figure 2.2 : Increasing sensitivity of various cells to radiation	13
Figure 4.1 : Low contrast resolution image (CTP 515)	24
Figure 4.2 : GE lightspeed plus multislice helical CT scanner (GE medical system)	27
Figure 4.3 : GE PathSpeed Diagnostic workstation	28
Figure 4.4 : Osirix Diagnostic workstation	28
Figure 4.5 : Measurement of abdominal dimension	31
Figure 5.1 : Distribution of control and study group of patient included in this study	32
Figure 5.2 : Age distribution of subjects	33
Figure 5.3 : Gender distribution of subjects	34
Figure 6.1 : CT abdomen image with 25 % dose reduction (mAs of 180) in patient with abdominal cross sectional area ≥ 800 cm^2	46
Figure 6.2 : CT abdomen image with standard dose (mAs of 240) in patient withabdominal cross sectional area ≥ 800 cm^2	46
Figure 6.3 : CT pelvis image with standard dose in patient with tranverse AP diameter ≥ 34.5 cm	47
Figure 6.4 : CT pelvis image using 25 % dose reduction (mAs of 180) in patient with tranverse AP diameter ≥ 34.5 cm	47

ABBREVIATIONS

AP – Anteroposterior

CT – Computed tomography

CTDI – Computed tomography dose index

HUSM – Hospital Universiti Sains Malaysia

kVp – tube energy

mAs – miliampere seconds (tube current)

MOH – Ministry of Health

MRI – Magnetic resonance imaging

MSAD – Multiple scan average dose

SNR – Signal Noise Ratio

TLD – Thermoluminiscent dosimeter

US FDA – United State Food and Drug Agency

CHAPTER ONE

INTRODUCTION

1.0 INTRODUCTION

The introduction of computed tomography (CT) in the 1970's led to a revolution in imaging. A further dramatic increase in the use of CT in the diagnosis of variety of pathologies come with the introduction of spiral CT in 1990 and multi detector row CT scanners in 1998 (Siegel MJ et al, 2004).

The broadened use of CT scan in clinical practice has raised concerns about mounting radiation exposure thus emphasizing the need for appropriate strategies to optimize and if possible, reduce dose due to CT scan (Kalra MK et al, 2004). Data in USA stated that while CT accounts for 11% of x-ray based examination, it delivers over two third of total radiation dose associated with medical imaging (Mettler FA, 1993).

Risks associated with radiation exposure are categorized to deterministic effects and stochastic effects. Deterministic effects are rarely seen with diagnostic x-ray based examination, including CT because radiation dose typically do not reach the threshold level. Indeed, the main risks to the subject are due to stochastic effect, which may result in cancer and genetic effects which occur in the offspring of the irradiated subject (Kalra MK et, 2004).

Among all parts of the body, abdomen and pelvis CT scan has the highest effective dose which is 10.0 mSv each. As for comparison effective dose for a single plain chest radiograph is 0.2 mSv, which made abdomen and pelvis CT scan hundred times higher dose. It is our concern when performing the CT scan, the radiation dose must be kept the minimum required dose particularly the lower abdomen and pelvis where the reproductive organs are situated. This is also important in those patient who required repeated CT scan evaluation in assessing response to chemotherapy or radiotherapy. We are also concerned about the pregnant lady who required abdomen and pelvis CT scan for example those who involved in motor vehicle accident and suspected to have intra abdominal injury. High radiation dose to the fetus may result in unpleasant events.

Several strategies can help to reduce population based dose from CT scan. These include limiting the use of CT to carefully identified indications, avoiding multiphase protocols, adequately addressing specific clinically issues, making judicious choices on when to repeat or to suggest follow up CT scan, and adjusting technical scanning parameters appropriately (Rehani MM, 2000). The tube voltage (kVp), tube current (mAs), scanning time, pitch, slice thickness and scanning volume are some of technical factors that influenced radiation dose from CT scan. Radiation dose is linearly related to tube current, scanning time and scanning volume.

In this study, only mAs is adjusted while other scanner parameters were kept constant. Adult population were chosen as most patient scheduled for CT in HUSM are from this group. At the moment, HUSM acquired GE Medical System Light Speed Plus since middle of 2001 which utilized the spiral or helical technology.

CHAPTER TWO

LITERATURE REVIEW

2.0 LITERATURE REVIEW

2.1 Introduction to CT scan

Tomography literally means a slice view of the patient, although the term sectional imaging is now preferred. CT generate images in transaxial sections ie. perpendicular to the axis of the x-ray tube about the body and generally perpendicular to the craniocaudal axis of patient body. It is not influenced by the properties of neighbour regions of the body. Therefore, they are able to display levels of contrast that truly represent subject contrast within the imaged section (Farr Physics for medical imaging, 2006). CT scan was introduced in the early 1970's. Originally described as CAT scan (computerized axial transverse scanning) was discovered in April 1972 by Godfrey N. Hounsfield, which earned him the award of the Nobel Prize in 1979.

The word computed was included in the description indicating the key role of the computer in the development of this technology. Now, CT scan does not only provide us the axial images but also produced coronal images and reformatted images in both coronal and sagittal views. The development in computer technologies over the succeeding years that the technologies has been transformed from basic transaxial imaging to true three dimensional representation of the body.

In early 1990's, helical (spiral) CT rejuvenated the role of CT in body imaging. This has further entrenched CT as the primary imaging modality for abdomen and pelvis. In mid 1990's, dual detector row CT scan was introduced. Since that time multi detector row CT (MDCT) has progressed through 4 row (quad), 8 row, 16 row, 32 row to 64 row scanners. MDCT has enabled remarkably fast CT scanning using thin sections and allow reconstruction of excellent quality images in any anatomic plane. It also allows long area coverage and multiphase imaging during contrast administration (Fundamental of body CT. 3rd Edition, 2006).

2.2 CT scan equipment

There are 3 major section of basic CT system:

- the imaging system (consist of gantry, x-ray tube, collimators and detectors).
- the computer systems.
- display system (operator and viewing console).

The gantry houses the x-ray tube and detectors. It is built so that it accommodates the patient in the center of the framework. The circular opening through which the patient moves during scanning is called the gantry aperture. The x-ray tube used in CT has special element that makes it different from a conventional x-ray tube. X-ray tube used in CT scan are able to endure significant stress due to large amounts of exposure made at consistently high miliamperes (tube current) and kilovolt peak. Special requirement of CT tubes are higher anode heating capacity which typically 1 to 3 millions heat units. High speed rotors are utilized for more efficient heat dissipation (Clinical Computed Tomography for the Technologist. 2nd edition, 1995).

The x-ray beam is collimated as a wide fan beam sufficient to cover the patient cross section at its widest. The prepatient (x-ray tube) collimator is located on the tube house limits the beam to the patient, thereby limiting patient dose. The pre detector collimator limits the x-ray beam to the detector. This collimator is located in front of the detector to maintain image quality by reducing scattered radiation.

Detectors are an important part of the CT scanner system, as they gathered the information for reconstruction of the images. It is basically a device that convert x-rays into electrical pulses, which are then fed into a computer for processing. Therefore the detector must have efficiency to detect x-ray photons, the stability to produce artifact free images, and a fast response time to detect an x-ray event, recovered and then detect the next one (Computed tomography technology, 1982).

The computer system comprises of two component which is the hardware and software. Hardware refer to the physical component of the computer. Software is a set of instructions that controls the function of a computer. CT scanners use either an array processor or microprocessor to process scan data into an image. It is this part of the computer that uses mathematical equation called algorithm. Once the image is reconstructed with algorithm, it is displayed in a format called matrix. Matrix is an array of rows and columns of pixels. As the matrix sizes increases, the resolution of the CT images improves. The CT image is most commonly calculated on a 512 x 512 matrix, although 256 x 256 and 1024 x 1024 matrix may also be used. It should be recognized that each pixel should be more correctly be described as a voxel, it is a volume element having three dimensions with a depth that is equal to the thickness of the section (Farr physics for medical imaging, 2006).

The image display system is the equipment that enable us to view and manipulate the image which can be at the operator or viewing console. Operator's console is where the scanning procedure is controlled. Patient information namely the registration number, name, sex and age are also entered here to be displayed on data page. The operator's console is also where scanning parameters such as miliampere (mAs), scan time, kilovolt peak, slice thickness and others were selected. Viewing console is where the image information is manipulated by control buttons to obtain maximum information. It allows adjustment of density and contrast, and with the availability of software program, it allows multiplanar reformatted image.

2.3 Image quality and artifacts in CT scans

2.3.1 Image quality

Image quality (clarity) is the visibility of diagnostically important structure in the CT image. The factors that effect quality are all interrelated. The three factors that are intimately tied together include noise, resolution and patient exposure.

Noise or quantum mottle referred to deviation from uniformity, represented as statistical fluctuations. Standard deviation is a measurement of noise. It is determined by numerous factors including quantity and quality of x-ray beam, the number and efficiency of the detectors, the amount of absorber in the path of the beam, the number and volume of picture element and scan tissue (Christensen's Physics for Diagnostic Radiology).

Resolution has two components, namely the spatial and contrast resolution. Spatial resolution of a CT unit is its ability to display as separate images, two objects that are very close to each other. Contrast resolution of a CT unit is the ability to display, as distinct images, area that differ in density by small amount. Spatial and contrast resolution are related to each other and to the radiation dose absorbed by the detector. Spatial resolution measurement are determined by using test objects of high contrast. It is influenced by various factors namely the scanner design (x-ray tube, focal spot size, detector size and magnification), computer reconstruction and the display. In contrast