SIZE-SPECIFIC DOSE ESTIMATES FOR ADULT ABDOMEN-PELVIS COMPUTED TOMOGRAPHY EXAMINATIONS IN JOHOR

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To my beloved siblings,

Aunts and uncles,

And all of my friends,

Without whom none of my success would be
possible

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All praise to the Almighty, were it not for His grace, none of these can be achieved.

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ABSTRACT

Accurate dose monitoring in computed tomography (CT) is important as CT provides high radiation exposure to the patient compared to other medical imaging modalities. The determination of size-specific dose estimate (SSDE) which takes into account the patient thickness has further facilitated radiation dose calculation in medical field. Present study has been conducted to determine firstly the difference between the average patient size and polymethymethacrylate phantom size, secondly the effects of various patient dimensions on the SSDE, and finally to verify the relationship between the SSDE and the volume CT dose index ($CTDI_{vol}$), as well as that of between the SSDE and the patient size. One hundred abdomen-pelvis CT images have been utilized for coefficient of variation (CV) analysis using different patients' thickness measurements. Descriptive statistics and Mann-Whitney test have been used to obtain the significant difference, *p* values. Simple linear regression model was plotted to determine the correlation between the SSDE and $CTDI_{vol}$, as well as that of between the SSDE and patient's thickness by referring to the summation of anterior-posterior and lateral (AP+Lateral) diameter. Routine abdomen-pelvis protocols considered in this study are in agreement with guidelines with a mean SSDE and $CTDI_{vol}$ of 15.5 ± 4.1 mGy and 11.4 ± 4.6 mGy, respectively. The SSDEs measured on the axial image and localizer radiograph show no significant difference, while the SSDEs derived from AP+Lateral diameter show a lower CV compared to other size descriptors, thus the latter is recommended to be used in the future SSDE calculation. Results show that the SSDE provides a better measure of the patient radiation dose value than the $CTDI_{vol}$. It reduces the underestimation and overestimation problems of using phantoms in calculation of the $CTDI_{vol}$. In conclusion, a promising approach using the SSDE as a measure of patient radiation dose can provide accurate dose estimation in clinical study compared to other approach based on the $CTDI_{vol}$.

ABSTRAK

Pemantauan dos yang tepat dalam tomografi berkomputer (CT) adalah penting kerana CT memberikan dedahan sinaran yang tinggi kepada pesakit berbanding modaliti pengimejan perubatan yang lain. Penentuan anggaran dos saiz tentu (SSDE) yang mengambilkira ketebalan pesakit dalam pengiraan telah memudahkan lagi pengiraan dos dalam bidang perubatan. Kajian ini telah dijalankan pertamanya untuk menentukan perbezaan antara saiz purata pesakit dan saiz fantom *polymethymethacrylate*, keduanya untuk menentukan kesan kepelbagaian dimensi pesakit terhadap SSDE dan yang terakhir untuk menentusahkan hubungan antara SSDE dengan indeks dos CT isipadu ($CTDI_{vol}$), dan SSDE dengan saiz pesakit. Seratus imej CT abdomen-pelvis telah digunakan untuk tujuan analisis pekali ubahan (CV) dengan menggunakan ukuran ketebalan pesakit yang berbeza. Statistik perihalan dan ujian Mann-Whitney telah digunakan untuk mendapatkan nilai perbezaan signifikan, *p*. Model regresi linear diplotkan untuk menentukan korelasi antara SSDE dengan $CTDI_{vol}$, dan SSDE dengan saiz pesakit dengan merujuk kepada hasil tambah antara diameter anterior-posterior dan lateral (AP+Lateral). Protokol abdomen-pelvis dalam kajian ini didapati selaras dengan garis panduan dengan nilai min SSDE dan $CTDI_{vol}$ masing-masing ialah 15.5 ± 4.1 mGy dan 11.4 ± 4.6 mGy. SSDE yang dianggar daripada imej paksi dan radiograf *localizer* tidak menunjukkan perbezaan yang signifikan, manakala SSDE yang diperolehi daripada AP+Lateral diameter menunjukkan CV yang lebih rendah berbanding pemerihal saiz yang lain, justeru pendekatan kedua ini disarankan dalam pengiraan SSDE pada masa hadapan. Keputusan menunjukkan bahawa SSDE memberikan ukuran nilai dos radiasi pesakit lebih baik berbanding $CTDI_{vol}$. Ia mengurangkan masalah anggaran dos yang berlebihan dan berkurangan yang disebabkan oleh penggunaan fantom dalam pengiraan $CTDI_{vol}$. Kesimpulannya, satu pendekatan berpotensi yang menggunakan SSDE sebagai ukuran dos radiasi pesakit boleh memberikan anggaran dos yang lebih tepat dalam amalan klinikal, berbanding pendekatan lain yang berasaskan $CTDI_{vol}$.

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LIST OF SYMBOLS

f_{size}	-	Size dependent conversion factor
p	-	Pitch
nT	-	Total detector length
D_T	-	Tissue absorbed dose
W_T	-	Tissue weighting factor
W_R	-	Radiation weighting factor
k	-	Conversion factor of effective dose from DLP
$k_{abdomen\text{-}pelvis}$	-	Conversion factor of effective dose from DLP for abdomen-pelvis examination
$k_{abdomen}$	-	Conversion factor of effective dose from DLP for abdomen examination
k_{pelvis}	-	Conversion factor of effective dose from DLP for pelvis examination
x	-	Data
$\bar{x}$	-	Mean
N	-	Number of data
r	-	Correlation of x-axis and y-axis
SD_Y	-	Standard deviation of data on y-axis
SD_X	-	Standard deviation of data on x-axis

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LIST OF ABBREVIATIONS

AAPM	-	American Association of Physicist in Medicine
AEC	-	Automatic exposure control
AP	-	Anterior-posterior
ATCM	-	Automated tube current modulation
CT	-	Computed Tomography
CTDI	-	Computed Tomography Dose Index
CV	-	Coefficients of variations
DICOM	-	Digital imaging and communication
DLP	-	Dose-length product
DRL	-	Diagnostic reference level
ICRP	-	International Commission on Radiological Protection
LAR	-	Lifetime attributable risk
MRI	-	Magnetic resonance imaging
NDRL	-	National Diagnostic Reference Level
PACS	-	Picture archiving and communication system
PMMA	-	Polymethyl-methacrylate
SD	-	Standard deviation
SSDE	-	Size-specific dose estimates
TCM	-	Tube current Modulation
TLD	-	Thermoluminescence dosimeter
UNSCEAR	-	United Nations Scientific Committee on The Effects of Atomic Radiation

CHAPTER 1

INTRODUCTION

1.1 Background of Study

The discovery of X-ray by German physicist, Wilhelm Roentgen, in 1895 was received extraordinary interest by both scientist and public. While public were amazed by the ability of X-ray to pass through solid matter, scientists were fancied by the existence of wavelength shorter than light. X-ray has generated new possibilities in physics and led to application in surgery and medicine. By less than a year after discovery, several medical radiographs had been made which guide surgeons in their work and battlefield physicians to locate bullets in wounded soldiers. Nowadays, X-ray has been utilized worldwide in the field known as radiology, which grew around the continuous advance of technology. For each day the use of X-ray in ionizing radiation for medical imaging reach more than ten million in diagnostic radiology and hundred thousand in nuclear medicine, around the world (UNSCEAR, 2010).

The development of X-ray result in various modalities in radiology, such as fluoroscopy, computed tomography (CT), and mammography. Among them, CT are the only modality which able to access a series of detailed cross sectional images by combining multiple X-ray projections taken from different angle, thus yield higher contrast images compared with conventional radiography (Figure 1.1). It was first discovered by Hounsfield in 1972 which his achievement was a remarkable breakthrough and took the entire medical world by surprise. Two years after the discovery, 60 clinical CT scanner have been installed for commercial medical used.

The development continue with the first clinical spiral CT examination in 1989, introduction of multi-slice scanners in 1998, and until 2004, more than 40 000 clinical CT scanner have been installed worldwide (Kalender, 2006).

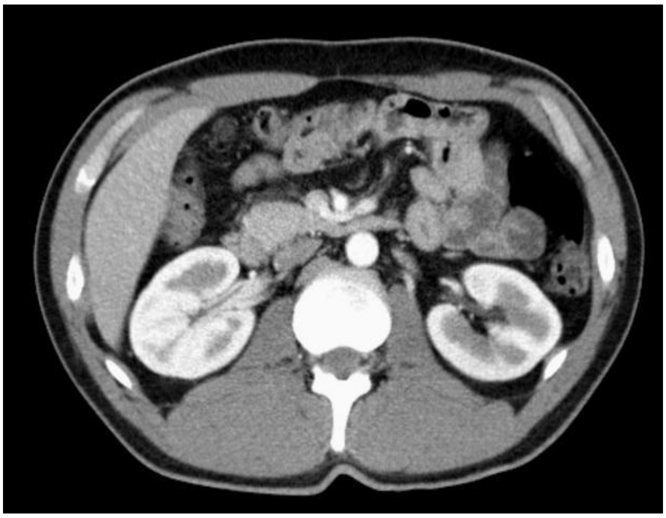


Figure 1.1 A cross sectional image of abdomen during abdominal CT imaging. Clear image of left and right kidney as well as aorta and intestine are helpful for clinical practice

The benefits of CT in medical are widely known as it give precise, three dimensions images of certain body parts, such as brain, heart, blood vessel, lung, and pelvis. In some cases, contrast material might be used to access better images of injection area. CT scanners are being increasingly utilized by radiology and radiotherapy departments for traditional roles of patient diagnosis and cancer staging, and are under continual technical development which resulting in other clinical application. With massive usage of CT, it has become the most preferable modality in medical imaging.

On the other hand, the dose to patient may be significantly increased with the increasing complexity of scanner and CT examination. In fact, radiation dose of CT are the highest among medical imaging modalities due to continuous exposure along

Z-axis on patient with 42% of total collective effective dose comes from CT examination (UNSCEAR, 2010). Surveys show that radiation dose of CT might even exceed threshold dose and thus increase the possibility of radiation-induced cancer (Rehani *et al*. 2012; Naumann *et al*. 2014). The cause of excessively high patient dose can be attributed to poor equipment condition and poor optimization of scanner radiographic protocols. Therefore, the increasing complexity of CT examination requires careful dose monitoring by medical physicist as well as radiologist and radiographer to ensure that appropriate examination conditions are being practice.

The drawback of CT causes increasing concerned of potential health hazards as well as various initiatives and actions of researchers. At the same time, efforts were made and underway to reduce patient's radiation exposure without undermine image quality and diagnostic value. Many studies focused on finding the most accurate dosimetry, although, current existing dosimetry are still in use worldwide (Jessen *et al.* 1999; Fearon *et al.* 2011; Tsalafoutas *et al.* 2012; Edyvean 2013). For instances, size-specific dose estimate (SSDE) method based on calculation derived from current dosimetry method, Monte Carlo method which based on simulation, as well as thermoluminescence dosimeter (TLD) for direct radiation detection.

1.2 Problem Statement

CT is not only known by its high performance in radiological diagnostics, but also classified as high dose examination procedure. Therefore, special attention shall be given to reduce the drawback of CT, including limiting or reducing the radiation dose level. This highlights the importance of dose information for each patient during every CT examination. However, patient dose has been difficult to obtain and are often answered with great uncertainty and imprecision, as it depends on a number of parameters and wide range of body shape, height, and weight of the patient (Kalender, 2011).

Current dosimetry method to estimate patient dose, use in clinical practice is CT dose index (CTDI) method (Shope *et al.*,1981). However, the used of CTDI as representing patient dose are debatable and the criticisms are based on two arguments. First, measurements of CTDI were made using 100 mm pencil ionization chamber which was not long enough to measure scattered radiation distribution of patient. Second, polymethylmethacrylate (PMMA) phantoms used to construct CTDI were shorter than patient size, specifically shorter than adult torso. Basically, CTDI only measures radiation output of the scanner, or in other words, CTDI value tells physicists how the scanner was operated. In fact, previous study proved that the adaption of CTDI value as patient dose might underestimate the real value, specifically as much as 40% (McCollough *et al.*, 2011).

In clinical practice, patients are varies in size and scan length are based on patients size and type of examination. Therefore, the use of phantom to estimate dose to a specific patient will underestimate the actual absorbed dose for smaller patient and overestimate actual absorbed dose for obese patient (McCollough *et al.*, 2011). The practice of display the CTDI value on the scanner console and patient dose report has confused many individual. This continuous unresolved problem has led to the establishment of new dosimetry quantity by American Association of Physicists in Medicine (AAPM) known as size-specific dose estimates (SSDE).

SSDE are basically an estimation of patient's tissue dose which dependent on $CTDI_{vol}$ and patient size. To estimate SSDE, one needs to have information on patient size, which was then converted into conversion factor, f_{size}. The conversion factors established by AAPM Report 204 are the results from four independent research groups, whose studies the potential of size dependent factors to estimate patient dose from $CTDI_{vol}$. In other words, SSDE paired $CTDI_{vol}$ with patient size, and proved to have accuracy in estimating patient dose by 10% more than $CTDI_{vol}$ (Brady and Kaufman, 2012).

However, Noferini *et al.* (2014) agree that errors may occur depend on how patient dimension are determine and which size descriptors should be used. Variation of SSDE has been observed on the same patient with different method of

SSDE calculation, although all size descriptors were measured on the same slice. Present study hypothesize that there may be significant differences between $CTDI_{vol}$ and SSDE and that the latter calculation may be affected by the method of obtaining patient dimension. In addition, inadequate study of SSDE was observed, specifically in Malaysian practice, thus motivate the initiation of current study.

1.3 Research Objectives

The aims of the current study can be summarized as follow:

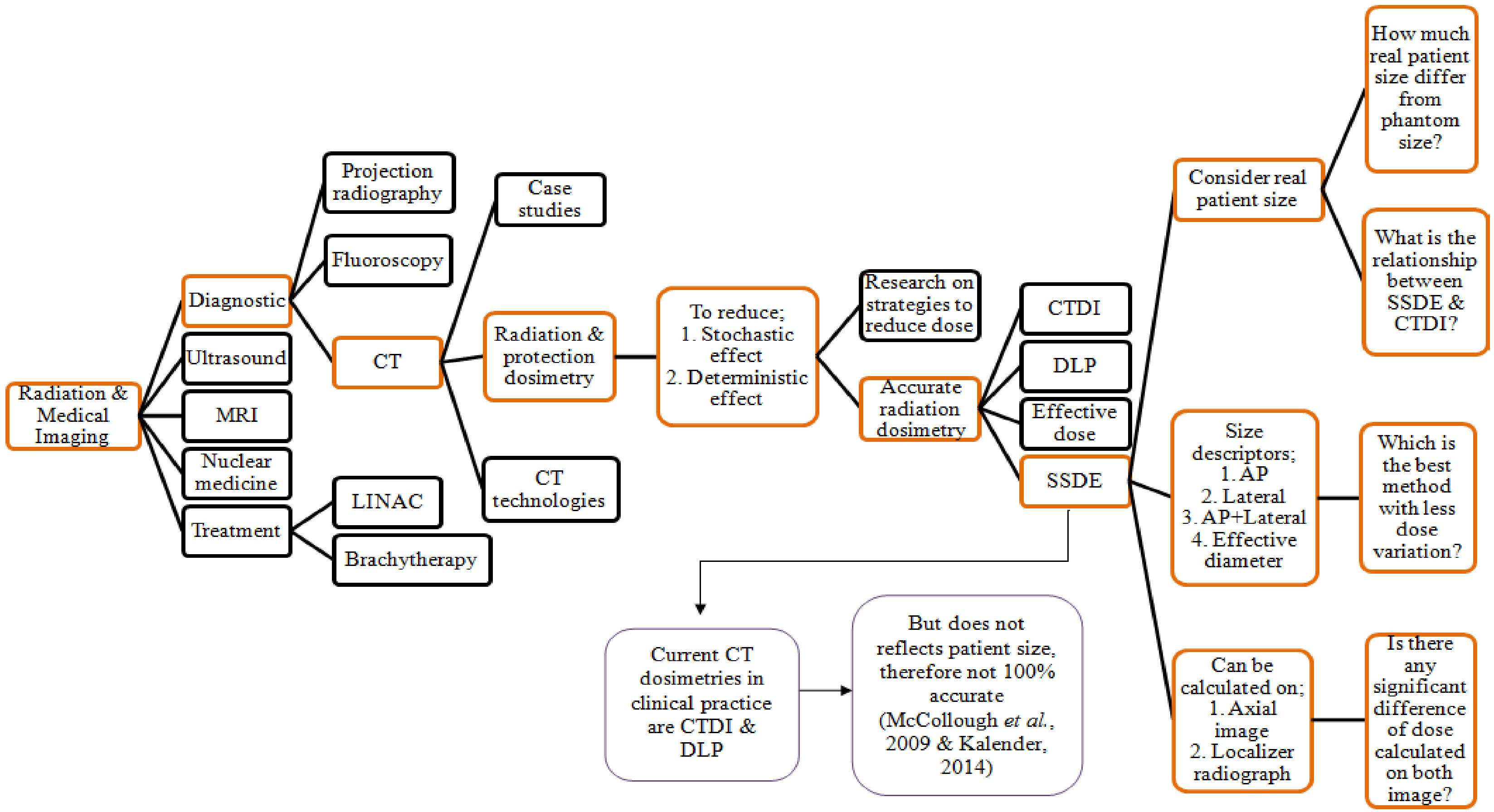
i. To determine the differences between patient size and PMMA phantom

ii. To determine the effect of variations in patient thickness obtained from axial image and localizer radiograph on the calculation of SSDE.

iii. To verify the relationship between SSDE, $CTDI_{vol}$ and patient size.

1.4 Scope of Study and Significance of Study

The study was administered at a hospital which equipped with one CT scanner. The findings represents dose at the hospital involved as well as other hospital with same CT scanner and same abdomen-pelvis protocols. Thus, findings cannot be described as dose of the whole nation or region population. Nevertheless, findings of this study will redound to the benefit of society considering that proper dose monitor plays an important role in CT dose optimization. In addition, the greater number of published studies of reporting CT dose and dose optimization techniques justified the need for more effective dose metrics. Medical practitioner who applies the recommended approach of SSDE derived from the results of this study will be able to gain less variation with more accurate dose value. Patients will be informing on real dose estimation rather than scanner output value which mistakenly believes as patient dose. For the researchers, the study will help them uncover the relation between SSDE and other important parameters and help to improve knowledge on SSDE level in Malaysian practice.



Objectives: The prominence goal of this study is to construct a workflow of SSDE calculation during clinical practice by determine the best method of calculation. Study also highlights the importance of SSDE to be accessible during practice. In general, study review the SSDE level in abdomen-pelvis CT examination, thus added to the limited studies of SSDE in Malaysia. In future, findings can be used as a supplementary document of the baseline information in recent SSDE situation of CT dosimetry in Malaysia.

Figure 1.2 Schematic diagram of the study

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