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

NUR ASHIQIN BINTI BAHRUD DIN

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

NUR ASHIQIN BINTI BAHRUD DIN

A thesis submitted in fulfilment of the
requirements for the award of the degree of
Master of Philosophy

Faculty of Science
Universiti Teknologi Malaysia

AUGUST 2017
To my beloved siblings,

Aunts and uncles,

And all of my friends,

Without whom none of my success would be possible
ACKNOWLEDGEMENT

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

Foremost, I would like to thank my supervisor, Dr Suhairul Hashim. His enthusiasm has made it a pleasure to work with him. I am especially grateful for his assistance, advice and encouragement during the study. Finally, I’d like to thank him for the time and effort in proof reading this thesis.

Near the beginning of this study I was assisted by Mr Khalis Abdul Karim especially in data collection and knowledge on medical imaging and clinical practice. His generous assistance and advice came when it was needed the most, without that I might never have completed the project.

I would like to express my sincere gratitude to Miss Ang Wee Chin for all the proof reading of my papers and thesis. I wish her and Miss Nasuha Salehhoon the best for their study.

Thanks to all the folks at the Department of Radiology, Hospital Sultanah Aminah and Hospital Permai for the collaboration and cooperation, especially Miss Diana. Without her sacrifices and enthusiasm this study would have been in vain.

Finally, and most importantly, I would like to thank my family and friends. Thank you to my siblings for encouraging me to achieve my dream, despite the situation we are facing. I hope this thesis will encourage my younger siblings to never give up in their studies. Special thanks to Miss Nabilah, Miss Khadijah, Mrs Fatin and Miss Hajira for all the support and encouragement over the years.

May Allah repay all your kindness.
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 polymethylmethacrylate 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\text{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\text{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\text{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\text{vol}. It reduces the underestimation and overestimation problems of using phantoms in calculation of the CTDI\text{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\text{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 kpelbagaian dimensi pesakit terhadap SSDE dan yang terakhir untuk menentusahkan hubungan antara SSDE dengan indeks dos CT isipadu (CTDI\text{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\text{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\text{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\text{vol}. Ia mengurangkan masalah anggaran dos yang berlebihan dan berkurangan yang disebabkan oleh penggunaan fantom dalam pengiraan CTDI\text{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\text{vol}.
## TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>CHAPTER</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>DECLARATION</td>
<td></td>
<td>ii</td>
</tr>
<tr>
<td>DEDICATION</td>
<td></td>
<td>iii</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENT</td>
<td></td>
<td>iv</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td></td>
<td>v</td>
</tr>
<tr>
<td>ABSTRAK</td>
<td></td>
<td>vi</td>
</tr>
<tr>
<td>TABLE OF CONTENTS</td>
<td></td>
<td>vii</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td></td>
<td>xi</td>
</tr>
<tr>
<td>LIST OF EQUATIONS</td>
<td></td>
<td>xiv</td>
</tr>
<tr>
<td>LIST OF SYMBOLS</td>
<td></td>
<td>xv</td>
</tr>
<tr>
<td>LIST OF APPENDICES</td>
<td></td>
<td>xvi</td>
</tr>
<tr>
<td>LIST OF ABBREVIATIONS</td>
<td></td>
<td>xvii</td>
</tr>
<tr>
<td>1</td>
<td>INTRODUCTION</td>
<td></td>
</tr>
<tr>
<td>1.1</td>
<td>Background of Study</td>
<td>1</td>
</tr>
<tr>
<td>1.2</td>
<td>Problem Statement</td>
<td>3</td>
</tr>
<tr>
<td>1.3</td>
<td>Research Objectives</td>
<td>5</td>
</tr>
<tr>
<td>1.4</td>
<td>Scope of Study and Significance of Study</td>
<td>5</td>
</tr>
<tr>
<td>1.5</td>
<td>Thesis Outline</td>
<td>7</td>
</tr>
</tbody>
</table>
LITERATURE REVIEW

2.1 Introduction 8
2.2 Overview of CT 8
2.3 CT Technologies 10
2.4 CT Dosimetry Methods 12
2.5 Size-Specific Dose Estimates 16
2.6 Diagnostic Reference Level (DRL) 20
2.7 Abdomen-Pelvis CT Scan 21
2.8 Effective Dose 21

METHODOLOGY

3.1 Introduction 25
3.2 Examination Protocol 27
3.3 Thickness Measurement 30
3.4 Dose Estimation 34
3.5 Data Analysis 37
   3.5.1 Comparison of SSDE values 38
   3.5.2 Relationship determination between SSDE, CTDI_vol and patient size 39
3.6 Effective Dose Determination 43

RESULTS AND DISCUSSION

4.1 Introduction 45
4.2 Study Population 46
4.3 Patient’s Size 48
4.4 SSDE 52
4.5 Relationship of SSDE with other parameters 55
  4.5.1 SSDE, CTDIvol and patient size 55
4.6 Effective Dose 61

5 CONCLUSION
  5.1 Introduction 62
  5.2 Recommendations and Future Studies 64

REFERENCES 65

APPENDIX 73
# LIST OF TABLES

<table>
<thead>
<tr>
<th>TABLE NO.</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Phases of CT development in a comparison from 1972 to 2004 (Kalender, 2011)</td>
<td>10</td>
</tr>
<tr>
<td>2.2</td>
<td>Summary of SSDE studies specifically in the effort to establish methods to estimate organ dose from SSDE value</td>
<td>19</td>
</tr>
<tr>
<td>2.3</td>
<td>Effective dose weighting factors from ICRP 103 (ICRP, 2007)</td>
<td>22</td>
</tr>
<tr>
<td>3.1</td>
<td>Lists of conversion factor provided by AAPM based on 32 cm PMMA phantoms as a function of patient dimensions</td>
<td>35</td>
</tr>
<tr>
<td>4.1</td>
<td>Average scan parameters and dose as well as standard deviation (SD) values</td>
<td>46</td>
</tr>
<tr>
<td>4.2</td>
<td>Comparison between present study and DRLs published by certain countries</td>
<td>47</td>
</tr>
<tr>
<td>4.3</td>
<td>Descriptive statistics of patient thickness measured on axial image and localizer radiograph</td>
<td>49</td>
</tr>
<tr>
<td>4.4</td>
<td>Descriptive statistics of SSDE value estimated using patient thickness measured on axial image and localizer radiograph</td>
<td>53</td>
</tr>
<tr>
<td>4.5</td>
<td>Comparison of CV and $R^2$ of present and previous studies involving the same AEC system</td>
<td>59</td>
</tr>
</tbody>
</table>
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>FIGURE NO.</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>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.</td>
<td>2</td>
</tr>
<tr>
<td>1.2</td>
<td>Schematic diagram of the study</td>
<td>6</td>
</tr>
<tr>
<td>2.1</td>
<td>Two projection beam geometries in CT; parallel beam geometry (left) and fan beam geometry (right) (Bushberg <em>et al.</em>, 2002)</td>
<td>11</td>
</tr>
<tr>
<td>2.2</td>
<td>CTDI phantom having two through-hole; one at the centre and another at the periphery of the phantom. 100 mm standard pencil ionization chamber is use for radiation measurement (The International Commission on Radiation Units and Measurements, 2012)</td>
<td>13</td>
</tr>
<tr>
<td>2.3</td>
<td>Dimension of AP and lateral, as well as effective diameter, which is the circle of equal area of body dimension</td>
<td>17</td>
</tr>
<tr>
<td>2.4</td>
<td>Three types of phantoms in computational simulation. Top image is stylized phantoms of XCAT. Below (left) are phantoms used in ImPACT software and right image are male and female phantom used in CT-Expo</td>
<td>24</td>
</tr>
<tr>
<td>3.1</td>
<td>Summary of experimental procedures</td>
<td>26</td>
</tr>
<tr>
<td>3.2</td>
<td>Siemens Somatom 16-Slice scanner provided in the hospital for CT examination.</td>
<td>28</td>
</tr>
</tbody>
</table>
3.3 Scanning length of abdominal-pelvis CT examination

3.4 Dose report of patient during CT examination. Details of protocol and patient were listed in the report which can be access by medical practitioner

3.5 Illustration of transverse plane, sagittal plane and frontal plane which derived axial image and localizer radiograph (Muaz, 2015)

3.6 Thickness measurement of AP and Lateral diameter on (a) axial images and (b) and (c) localizer radiograph using *itk*-SNAP software, which (b) is frontal localizer radiograph used to measure Lateral diameter and (c) is lateral localizer used to measure AP diameter

3.7 Dose profile along Z-axis with tube potential of 120 kV. A range of scan lengths are indicated in the figure (Nakonechny *et al*., 2005)

3.8 An example of centre slice which patient thickness were measured on the tomography image using electronic calliper provided by the software

3.9 Boxplot graph used in this study which the box plot the central rectangle by 1st quartile to 3rd quartile values. A segment inside the rectangle shows the median and the whiskers above and below the box represents minimum and maximum values

3.10 Screenshot of tabular results in GraphPad Prism 7 which *p* value, $R^2$ value and the equation were calculated

3.11 The regression model plotted by GraphPad Prism 7

3.12 Linear regression model used in this study consists of three different lines which are upper
confidence band, best-fit line and lower confidence band

4.1 Body dimension of patients undergoing abdomen-pelvis CT compared with 32-cm phantom. Ellipse reflects patient cross-sections in the middle of scanned region along Z-axis. Circle reflects cross-section of referenced phantom used in the calculation of CTDI$_{vol}$

4.2 Patient sizes shown in circular shape which have the same area as real cross section, defined by effective diameter. Black circle reflects cross sectional of 32 cm phantom used to generate CTDI$_{vol}$

4.3 Boxplot showing the distribution of CTDI$_{vol}$ by three subgroups of patient size. Horizontal line inside each box denotes median. Dotted lines and whiskers denote 95% upper and lower confidence intervals

4.4 Boxplot showing the distribution of SSDE (mGy) by three subgroups of patient size. Horizontal line inside each box denotes median. Dotted lines and whiskers denote 95% upper and lower confidence intervals

4.5 Linear regression model between tube output (CTDI$_{vol}$) and patient size. $R^2$, $p$ value and equation of correlation were shown in the figure

4.6 Linear regression model between patient sizes with SSDE. $R^2$, $p$ value and equation of correlation were shown in the figure

4.7 Linear regression model of CTDI$_{vol}$ and SSDE plotted using equation stated in the figure
# LIST OF EQUATIONS

<table>
<thead>
<tr>
<th>EQUATION NO.</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Equation for CTDI&lt;sub&gt;w&lt;/sub&gt;</td>
<td>13</td>
</tr>
<tr>
<td>2.2</td>
<td>Equation for CTDI&lt;sub&gt;vol&lt;/sub&gt;</td>
<td>14</td>
</tr>
<tr>
<td>2.3</td>
<td>Equation for SSDE</td>
<td>16</td>
</tr>
<tr>
<td>2.4</td>
<td>Equation for effective dose by weighting factors</td>
<td>22</td>
</tr>
<tr>
<td>2.5</td>
<td>Equation for effective dose by DLP</td>
<td>23</td>
</tr>
<tr>
<td>3.1</td>
<td>Equation for effective diameter</td>
<td>31</td>
</tr>
<tr>
<td>3.2</td>
<td>Equation for mean values</td>
<td>37</td>
</tr>
<tr>
<td>3.3</td>
<td>Equation for standard deviation</td>
<td>37</td>
</tr>
<tr>
<td>3.4</td>
<td>Equation for CV</td>
<td>39</td>
</tr>
<tr>
<td>3.5</td>
<td>Equation for slope calculation</td>
<td>40</td>
</tr>
<tr>
<td>3.6</td>
<td>Equation for correlation determination</td>
<td>41</td>
</tr>
<tr>
<td>3.7</td>
<td>Equation for conversion factor of abdomen-pelvis examination</td>
<td>43</td>
</tr>
<tr>
<td>3.8</td>
<td>Equation for effective dose considering the conversion factor value</td>
<td>44</td>
</tr>
</tbody>
</table>
LIST OF SYMBOLS

\( f_{\text{size}} \) - 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
\( k_{\text{abdomen-pelvis}} \) - Conversion factor of effective dose from DLP for abdomen-pelvis examination
\( k_{\text{abdomen}} \) - Conversion factor of effective dose from DLP for abdomen examination
\( k_{\text{pelvis}} \) - 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
\( \text{SD}_Y \) - Standard deviation of data on y-axis
\( \text{SD}_X \) - Standard deviation of data on x-axis
# LIST OF APPENDICES

<table>
<thead>
<tr>
<th>APPENDIX</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Raw data of Table 4.1</td>
<td>73</td>
</tr>
<tr>
<td>Acronym</td>
<td>Definition</td>
<td></td>
</tr>
<tr>
<td>----------</td>
<td>---------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>AAPM</td>
<td>American Association of Physicist in Medicine</td>
<td></td>
</tr>
<tr>
<td>AEC</td>
<td>Automatic exposure control</td>
<td></td>
</tr>
<tr>
<td>AP</td>
<td>Anterior-posterior</td>
<td></td>
</tr>
<tr>
<td>ATCM</td>
<td>Automated tube current modulation</td>
<td></td>
</tr>
<tr>
<td>CT</td>
<td>Computed Tomography</td>
<td></td>
</tr>
<tr>
<td>CTDI</td>
<td>Computed Tomography Dose Index</td>
<td></td>
</tr>
<tr>
<td>CV</td>
<td>Coefficients of variations</td>
<td></td>
</tr>
<tr>
<td>DICOM</td>
<td>Digital imaging and communication</td>
<td></td>
</tr>
<tr>
<td>DLP</td>
<td>Dose-length product</td>
<td></td>
</tr>
<tr>
<td>DRL</td>
<td>Diagnostic reference level</td>
<td></td>
</tr>
<tr>
<td>ICRP</td>
<td>International Commission on Radiological Protection</td>
<td></td>
</tr>
<tr>
<td>LAR</td>
<td>Lifetime attributable risk</td>
<td></td>
</tr>
<tr>
<td>MRI</td>
<td>Magnetic resonance imaging</td>
<td></td>
</tr>
<tr>
<td>NDRL</td>
<td>National Diagnostic Reference Level</td>
<td></td>
</tr>
<tr>
<td>PACS</td>
<td>Picture archiving and communication system</td>
<td></td>
</tr>
<tr>
<td>PMMA</td>
<td>Polymethyl-methacrylate</td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td>Standard deviation</td>
<td></td>
</tr>
<tr>
<td>SSDE</td>
<td>Size-specific dose estimates</td>
<td></td>
</tr>
<tr>
<td>TCM</td>
<td>Tube current Modulation</td>
<td></td>
</tr>
<tr>
<td>TLD</td>
<td>Thermoluminescence dosimeter</td>
<td></td>
</tr>
<tr>
<td>UNSCEAR</td>
<td>United Nations Scientific Committee on The Effects of Atomic Radiation</td>
<td></td>
</tr>
</tbody>
</table>
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).

![CT Scan of Abdomen](image)

**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\textsubscript{vol} and patient size. To estimate SSDE, one needs to have information on patient size, which was then converted into conversion factor, $f_{\text{size}}$. 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\textsubscript{vol}. In other words, SSDE paired CTDI\textsubscript{vol} with patient size, and proved to have accuracy in estimating patient dose by 10% more than CTDI\textsubscript{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 determining 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
REFERENCES


performance of a 64-channel dual-source CT scanner. Radiology, 243(3), 775–784.


Strauss, K. J. (2012). KERMA ratios vs. SSDE: is one better at estimating pediatric CT radiation doses? Pediatric Radiology, 45, 525-526.


