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Kertas Asli/*Original Articles*

Radiation Dose Comparison in CT Thorax, CT Abdomen and CT Thorax-Abdomen-Pelvis (TAP) Using 640-and 160-Slice Computed Tomography (CT) Scanners

(Perbandingan Dos Sinaran dalam Pemeriksaan Tomografi Berkomputer (CT) Toraksik, Abdomen dan Toraksik-Abdomen-Pelvis (TAP) antara 640 dan 160 Hirisan)

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ABSTRACT

This study was carried out to compare the effective dose, size specific dose estimation (SSDE) and scan length between genders and between CT scanner with different slice number. A total of 245 set data of radiation dose and scan length for CT scanning procedure involving thorax, abdomen and pelvis regions were obtained retrospectively for comparisons. 111 patients (60 males and 51 females) were scanned using 160-slices CT scanner while 134 patients (71 males and 63 females) were scanned using 640-slices CT scanner. Generally, there were no significant differences in the radiation dose and scan length among genders. However, differences for SSDE in CT thorax and CT thorax-abdomen-pelvis (TAP) protocols exist whereby in CT thorax protocol, 640-slices CT scanner had a significantly higher value of SSDE (9.06±2.67 mGy) than that in 160-slices CT scanner (7.82±1.33 mGy). Similarly to the CT TAP protocol, whereby 640-slices CT scanner had a significantly lower value in SSDE (9.17±1.59 mGy) than that in 160-slices CT scanner (10.76±3.72 mGy). In conclusion, there was no significant difference in the radiation dose and scan length between genders but significant difference was only observed in SSDE due to the presence of body size variation among the study population especially in different CT scanners.

Keywords: Computed tomography; radiation dose; gender; 160-slices CT scanner; 640-slices CT scanner

ABSTRAK

Kajian ini dijalankan untuk membandingkan dos sinaran efektif, ukuran dos spesifik (SSDE) dan panjang imbasan antara jantina dan antara pengimbas tomografi berkomputer (CT) dengan bilangan hirisan yang berbeza. Sejumlah 245 set data terdiri daripada dos sinaran dan panjang imbasan untuk pemeriksaan CT yang melibatkan bahagian toraksik, abdomen dan pelvis telah diperoleh secara retrospektif untuk perbandingan. Seramai 111 orang pesakit (60 lelaki dan 51 wanita) diimbas menggunakan mesin imbasan CT 160-hirisan manakala 134 orang pesakit (71 lelaki dan 63 wanita) diimbas menggunakan mesin imbasan CT 640-hirisan. Pada amnya, tiada perbezaan yang ketara dalam dos sinaran dan panjang imbasan di kalangan jantina. Walau bagaimanapun, wujud perbezaan signifikan pada SSDE dalam protokol CT toraksik dan CT toraksik-abdomen-pelvis (TAP) pada mesin pengimbas berlainan hirisan di mana protokol CT toraksik menggunakan mesin CT 640-hirisan mempunyai nilai SSDE yang lebih tinggi (9.06 ± 2.67 mGy) daripada pengimbas CT 160-hirisan (7.82 ± 1.33 mGy). Begitu juga dengan protokol CT TAP, di mana pemeriksaan menggunakan mesin CT 640 hirisan mempunyai nilai yang jauh lebih rendah dalam SSDE (9.17 ± 1.59 mGy) berbanding pengimbas CT 160 hirisan (10.76 ± 3.72 mGy). Kesimpulannya, tidak terdapat perbezaan yang signifikan dalam dos sinaran dan panjang imbasan antara jantina tetapi perbezaan yang signifikan hanya diperhatikan dalam SSDE disebabkan adanya variasi saiz badan di kalangan populasi kajian terutama pada mesin pengimbas CT berbeza hirisan.

Kata Kunci: Tomografi berkomputer; dos sinaran; jantina; pengimbas CT 160 hirisan; pengimbas CT 640 hirisan

INTRODUCTION

Computed Tomography (CT) is a diagnostic imaging tool which is widely used in clinical setting to provide diagnosis for diseases. With the capability of providing 3-dimentional images and multiplanar reformations, CT becomes the most preferable tool for diagnosis other than having high sensitivity and specificity in the detection of major diseases (Almohiy 2014). To date, the slice number for CT scanner had achieved 640 slices.

In comparison to other modalities involving ionizing radiation such as general radiography and fluoroscopy, CT scan delivers a higher radiation dose to the patient (Almohiy 2014). For a single CT scan, with an average of two or three CT scan per study, the organ that is examined generally will obtain the dose ranging from 15 mSv to 30 mSv, depends on the scanner setting (Brenner & Hall 2007). With that, the dose delivered to the patient is a main concern. Previous studies had reported about the results for the changes of the radiation dose as the slice number of the CT scanner is increased (Karim et.al 2016; Fujii et al. 2009; Hsiao et al. 2010; Jaffe et al. 2010; Khan et al. 2011; Tsalafoutas & Koukourakis 2010). However, their results are different, at which there were increased radiation dose (Jaffe et al. 2010; Tsalafoutas & Koukourakis 2010), decreased radiation dose (Hsiao et al. 2010; Khan et al. 2011) and no change of the radiation dose value (Fujii et al. 2009).

SSDE is the estimation of the radiation dose by taking into account of the patient body size and it had been used in several studies to calculate SSDE for patient with different body sizes (Boone et al. 2011; Waszczuk et al. 2015). The value of SSDE was nearly one-to-one correlation with measured absolute organ dose. This situation is happened when the organ was fully located within the scan field of view (FOV). For those organs which are locating out of the scan FOV, a correction factor will be used for the calculation of the absolute organ dose (Brady et al. 2015). Yet, there is lack of information for the comparison and discussion of SSDE in terms of sex and slice number of CT scanner in these journals.

Despite the advancement of the technology for MSCT scanner, the amount of radiation dose delivered to the patient is still not prioritised. Therefore, this study is carried out to compare the effective dose, SSDE and scan length of the patient in terms of genders and slice number of the CT scanner for the procedure of CT Thorax/ Abdomen/ Pelvis. The finding of this study was expected to provide valuable information to radiologist and radiographer regarding to judicious use of MSCT scanner and the optimisation of the CT scanning parameter for different patients in the procedure of CT thorax/ abdomen/ pelvis.

METHODOLOGY

STUDY POPULATION

This is a cross sectional study by using retrospective data to compare effective dose, SSDE and scan length between genders as well as slice number of CT scanner. This study was approved by the institutional ethics committee. A total of 245 sets of CT scanning procedure involving the region of thorax, abdomen and pelvis were obtained retrospectively at the Department of Radiology, Universiti Kebangsaan Malaysia Medical Centre (UKMMC), Kuala Lumpur. The study was conducted from March 2017 to March 2018. All patients underwent CT examinations of thorax, abdomen and thorax-abdomen-pelvis (TAP) protocols with contrast medium were included in this study. However, patients below 18 years old, pregnant women and most of the complex CT examinations such as calcium scoring, CT guided biopsy, CT angiogram (CTA) and CT multi-phases examinations were excluded from the study.

SCANNING METHOD

All protocols were scanned using 640-slices CT Scanner (Aquilion One, Toshiba, Japan) and 160-slices CT Scanner (Aquilion Prime, Toshiba, Japan). Automatic tube current modulation (ATCM) was applied in all procedures.

CT THORAX PROTOCOL

For CT Thorax protocol, the scanner setting was set at tube voltage 120 kVp and pitch factor 0.813. Small focal spot was used in this protocol and the scan range was set at 50 cm. The slice thickness is reconstructed at 5 mm with the slice interval at 5 mm.

CT ABDOMEN PROTOCOL

CT abdomen protocol was performed with tube voltage 120 kVp, scan range of 80 cm and pitch factor 0.637. Slice thickness was reconstructed at 5 mm with slice interval at 5 mm.

CT THORAX-ABDOMEN-PELVIS (TAP) PROTOCOL

For CT TAP protocol, the scanner setting was adjusted with tube voltage 120 kVp, pitch factor 0.637 and scan range 100 cm. Slice thickness was reconstructed at 5 mm with a slice interval at 5 mm.

CONTRAST MEDIUM ADMINISTRATION

Contrast agent (Omnipaque 300 mgI/ml) was used for the procedure which involved the use of contrast medium. For CT thorax protocol, 80 ml of contrast agent was administered intravenously at a flow rate of 3.0 ml/s followed by 30 ml saline flush at a flow rate of 3.0 ml/s and the scan was delayed by 43 seconds. For CT abdomen protocol and CT TAP protocol, both of them used the same contrast medium administration setting, at which 100 ml of contrast agent was administered intravenously at a flow rate of 3.0 ml/s followed by 50 ml saline flush at a flow rate of 3.0 ml/s and the scan was delayed by 1 minutes.

RADIATION DOSE MEASUREMENT

All of the data were obtained from 640-slices CT Scanner (Aquilion One, Toshiba, Japan) and 160-slices CT Scanner (Aquilion Prime, Toshiba, Japan). The effective dose was estimated by multiplying Dose-Length Product (DLP) with conversion coefficient factor (E/DLP), k ($mSv \cdot mGy^{-1} \cdot cm^{-1}$). The DLP value was available on the CT scanner console and the k factors of 0.014 $mSv \cdot mGy^{-1} \cdot cm^{-1}$ was used for thoracic scanning region and 0.015 $mSv \cdot mGy^{-1} \cdot cm^{-1}$ was used for abdomen/pelvic and thorax/abdomen/pelvic scanning region. The value of dose conversion coefficient factor k for different scanning region was available in table 3 of the American Association of Physicist in Medicine report, AAPM Report No.96 (Boone et al. 2011).

In the measurement of size-specific dose estimation (SSDE), the measurement of body diameter in antero-posterior (AP) and lateral dimensions were compulsory for all patients. The measurements must include spinous process in AP dimension while mid-vertebral body should be included in the lateral dimension as shown in Figure 1. These measurements were obtained on the CT images at the specific slice level according to the scanning region using a computational software, Medweb Viewer version 0.6.270 (Nexsys Electronic Inc., USA). The measurement was done at the level of pulmonary trunk for CT thorax and transumbilical plane or at level of third lumbar vertebra for CT abdomen. In CT of thorax-abdomen-pelvis (TAP) region, the measurement level was marked at the level of twelfth thoracic vertebra.

SSDE was then calculated by multiplying $CTDI_{vol}$ of all patients with the value of dose conversion coefficient factor, k.

STATISTICAL ANALYSIS

Statistical analysis was performed using software SPSS version 22.0 for windows (SPSS Inc., USA). All of the data were presented in mean ± standard deviation. Independent t-test was performed for comparison of effective dose, SSDE and scan length in genders and slice number of CT scanner. Differences in P-value of <0.05 was considered as statistically significant.

RESULTS

PATIENT CHARACTERISTICS

A total of 245 subjects (131 males and 114 females) with mean age 59 ± 15 years old were involved in this study with 111 patients (60 males and 51 females) were scanned using 160-slices CT scanner while 134 patients (71 males and 63 females) were scanned using 640-slices CT scanner.

RADIATION DOSE AND SCAN LENGTH

The comparison of parameters such as effective dose, SSDE and scan length between male and female in 160-slice CT scanner and 640-slice CT scanner were presented in Table 1 and Table 2. The effective dose in CT thorax protocol was significantly higher in male (4.09±1.69 mSv) compared to that in female (2.82±1.18 mSv). Similarly, the scan length between males and females in 160-slices CT scanner also showed significant length whereby the scan length was longer in male (41.85±6.09 cm) compared to female (34.16±6.25 cm). Apart from effective dose and scan length in CT thorax protocol, there was no significant difference observed in other data of 160-slices CT scanner ($p > 0.05$).

In general, average DLPs for CT thorax in comparison between 160- and 640-slice CT were 243±110 mGy.cm versus 287±120 mGy.cm. The DLPs for CT abdomen and CT TAP were also compared between 160- and 640-slice CT and resulted with 845±682 mGy.cm versus 707±350 mGy.cm and 590±354 mGy.cm versus 522±167mGy.cm, respectively.

FIGURE 1a The measurement of body diameter in AP and Lateral dimension for calculation of SSDE of CT abdomen.

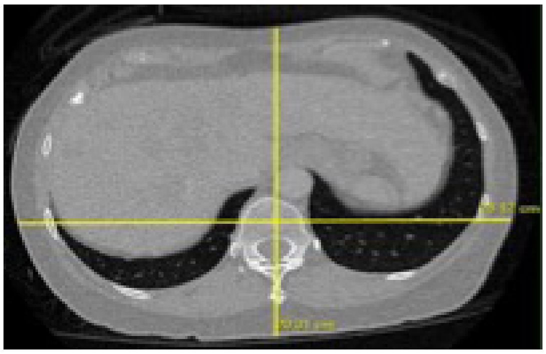

FIGURE 1b The measurement of body diameter in AP and Lateral dimension for calculation of SSDE of CT thorax.

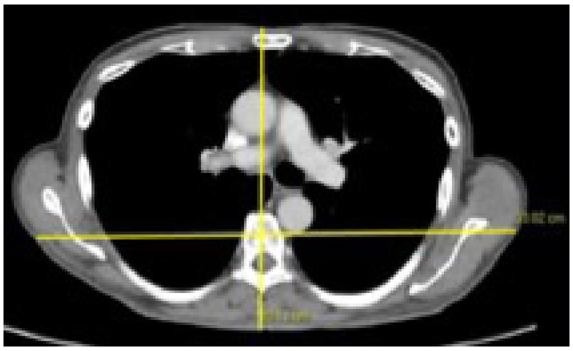

FIGURE 1c The measurement of body diameter in AP and Lateral dimension for calculation of SSDE of CT pelvis.

In 640-slices CT scanner, significant differences were only seen in SSDE of CT thorax protocol (p= 0.01) and scan length of CT TAP protocol (p= 0.01). The value of SSDE in female for CT thorax protocol was significantly higher than that in male with dose value of 9.86±3.10 mGy versus 7.68±0.36 mGy for female versus male, respectively. Unlike the finding of SSDE in CT thorax protocol, scan length in male for CT TAP protocol was significantly longer than that in female with the length of 55.49±10.40 and 46.65±10.60 cm for male and female, respectively.

For the comparison of effective dose between 160-slices CT scanner and 640-slices CT scanner, there was no much difference in the value of effective dose between these 2 scanners for all protocols (Figure 2) and no significant difference was observed among them (p> 0.05). Although the effective dose seems to be higher in 640-slice CT compared to that in 160-slice for CT thorax (4.02±1.68 mSv versus 3.40±1.55 mSv), the remaining effective doses for CT abdomen and CT TAP were remained lower in 640-slice compared to that in 160-slice CT with 10.61±5.25 mSv and 7.83±2.52 mSv versus 12.68±10.24 mSv and 8.85±5.31 mSv, respectively.

Figure 3 and Figure 4 showed the comparison of SSDE and scan length between 160-slices CT scanner and 640-slices CT scanner. Significant difference was observed in SSDE of CT thorax protocol between these two scanners (p= 0.03). The 640-slices CT scanner had a significant higher value of SSDE than 160-slices CT scanner in CT thorax protocol with the dose value of 9.06±2.67 mGy and 7.82±1.33 mGy for 640-slices and 160-slices CT scanner, respectively.

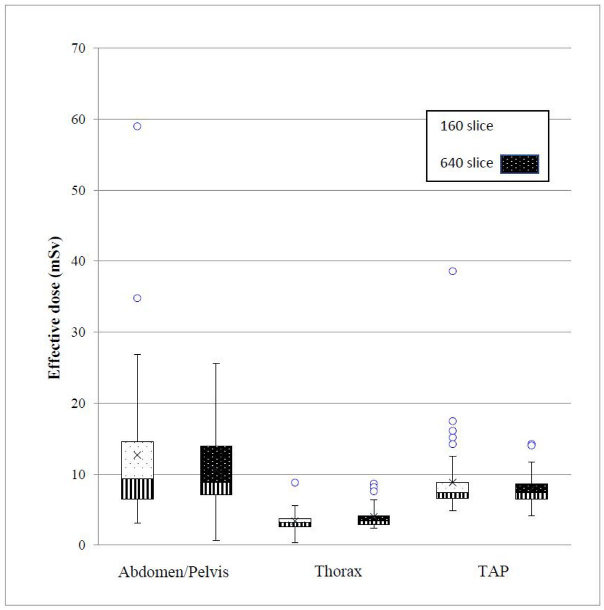

FIGURE 2 Box plot shows the mean effective dose for different scanning protocols in 160-slices and 640-slices CT scanner. The box indicates the first to third quartiles, with the line in the box indicating median quartile, and whiskers indicate the minimum and maximum values.

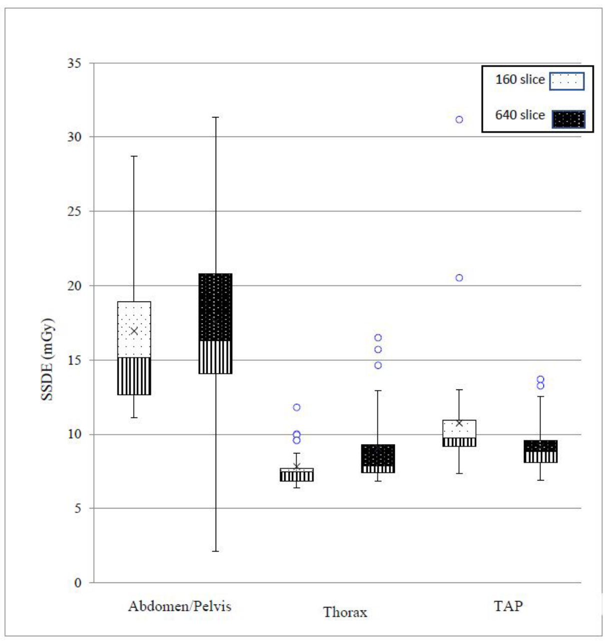

FIGURE 3 Box plot shows the mean SSDE for different scanning protocols in 160-slices and 640-slices CT scanner. The box indicates the first to third quartiles, with the line in the box indicating median quartile, and whiskers indicate the minimum and maximum values.

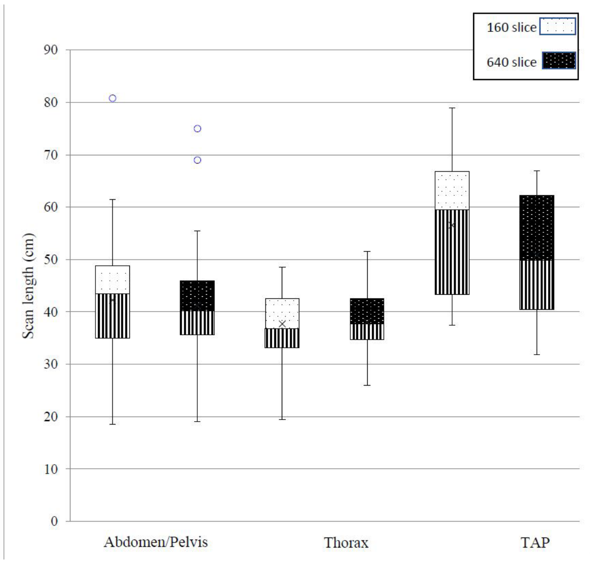

FIGURE 4 Box plot shows the mean scan length for different scanning protocols in 160-slices and 640-slices CT scanner. The box indicates the first to third quartiles, with the line in the box indicating median quartile, and whiskers indicate the minimum and maximum values.

Besides, CT TAP protocol also showed significant differences in both SSDE (p= 0.02) and scan length (p= 0.04). For SSDE in CT TAP protocol, 640-slices CT scanner had a significant lower value in SSDE than that in 160-slices CT scanner with dose value of 9.17±1.59 mGy for 640-slices CT scanner versus 10.76±3.72 mGy for 160-slices CT scanner. Similar to the finding of SSDE in CT TAP protocol, the scan length for CT TAP protocol in 640-slices CT scanner was significantly shorter than that in 160-slices CT scanner with length of 50.84±11.29 cm for 640-slices CT scanner versus 56.53±13.11 cm for 160-slices CT scanner.

DISCUSSIONS

Dose-Length Product (DLP) in mGy·cm can be calculated by multiplying CT Dose Index (CTDI) in mGy with scan length in cm (Mccollough et al. 2008). However, in our study, the multiplication of CTDI with scan length did not equal to DLP at which the value of DLP was greater than the product of CTDI and DLP. This was actually due to the over-ranging effect (Booij et al. 2017). According to Booij et al. (2017), over-ranging dose is the primary radiation which is delivered to the patient outside of the imaged volume. In spiral CT, the presence of the features such as increased detector width and higher pitch values will increase the over-ranging effect and hence, a higher dose is delivered to the patient. This phenomenon affecting all of CT dose results in our study whereby the estimation of dose by multiplying CTDI value with scan length will only result in under estimation of the total DLP.

The DLP values were compared with the national reference dose for CT thorax and CT abdomen. The DLPs measured for CT thorax in our study, 243±110 mGy.cm in 160-slice CT and 287±120 mGy.cm in 640-slice CT were still below the national DRL (600 mGy.cm) and other countries (Egypt at 420 mGy.cm; European standard at 650 mGy.cm). Although the DLP values measured for CT abdomen in 160- and 640-slice CT (845±682 mGy.cm and 707±350 mGy.cm) was above the national DRL (450 mGy.cm), it was still below than DRL published in other countries like Egypt (1425 mGy.cm) and European standard (780 mGy.cm). The DLP value for CT TAP can only be compared with DRL values from other countries as Malaysia did not provide DRL for CT TAP. Our DLP for CT TAP in 160- and 640-slice CT (590±354 mGy.cm and 522±167mGy.cm) were remained lower compared to DLP published in Egypt (1320 mGy.cm) (Karim et al. 2016; Salama et al. 2017).

In our study, different genders showed majority of non-significant difference (p>0.05) in the radiation dose obtained, either in 160-slices or 640-slices CT scanner. Although there is no significant difference of radiation dose in term of sex, however, the concerns still need to be taken for the radiation dose delivered to the patient with different genders. This is because females have more high carcinogenic radiosensitive organs (breast, ovaries and uterus) when compared with males who have only one high carcinogenic radiosensitive organs (testes) (Alkhorayef et al. 2017). Besides, Alkhorayef et al. (2017) also adds on that females are 1.6 times more radiosensitive to radiation than males. With that, extra cares and radiation protection, for example, shielding of the breasts with bismuth barrier should be taken for the female patients (Tamm et al. 2011).

In addition, no significant difference in the effective dose between 160-slices and 640-slices CT scanner was reported in our study (p>0.05). However, in a study conducted by Khoramian and Sistani (2017), they had reported that as the number of slice in CT scanner is increased, a lower value of radiation dose was produced, which was different with our study that showed no change in radiation dose as the slice number of CT scanner is increased. According to Khoramian and Sistani (2017), a lower radiation dose is produced due to the used of the shorter scan length and higher pitch factor in the scanning. In our study, the pitch factors which were used in both 160-slices and 640-slices CT scanner were same, with a value of 0.813 for CT thorax protocol and 0.637 for CT abdomen and CT TAP protocols. Furthermore, our study had also reported that there was no significant difference in the scan length of majority protocols. With that, the constant value of pitch factor and non-significant difference in scan length between 160-slices and 640-slices CT scanner had led to the non-significant difference in the effective dose between 160-slices and 640-slices CT scanner.

On the other hand, our study had reported that there was significant difference observed in SSDE of CT thorax and CT TAP protocol between 160-slices and 640-slices CT scanner. For CT thorax protocol, the significant difference could be caused by the variation in body size of the population in the study. In all of CT scanning examinations of this study, automatic tube current modulation (ATCM), a technique whereby it modulates the tube current to compensate for the variations in the attenuation of the body tissue of scanned subjects, was applied (Martin & Sookpeng 2016). The patients with larger body habitus were found to have a higher radiation dose in the CT scanning procedures with ATCM compared to those patients who were smaller in body sizes as higher tube output was needed to achieve the desired image quality (Israel et al. 2010; Meeson et al. 2010; Schindera et al. 2008). In our study, pitch factor among the machines was constant and the scan length was not significant between 160-slices and 640-slices CT scanner. Therefore, the body size of the patients which affects the amount of the tube current delivered by the CT scanner can affect the radiation dose obtained by the patients and cause the variation in the dose value obtained. For CT TAP protocol, apart from variation in body size of patient, the significant difference in SSDE can also be due to the significant difference in scan length, at which the significant longer scan length had led to a significant higher SSDE value in 160-slices CT scanner than those values in 640-slices CT scanner.

In the finding of SSDE also, it is found that both CT scanners delivered a lower radiation dose in CT thorax protocol, but give a higher radiation dose in CT TAP and CT abdomen protocol. The increment of the radiation dose in CT TAP and CT abdomen protocol can be due to the reduction in the pitch factor and the increase in the scan length between the protocol. A decrease in the pitch factor produced more overlaps in the anatomy and increased sampling at each location, which results in a higher radiation dose delivered to the patients (Raman et al. 2013). Compared to CT thorax protocol, scan length in CT TAP and CT abdomen protocol was higher due to the larger area of anatomy to be covered in the scanning. With a longer scan length, the exposure time of the patient was increased and hence, the radiation dose delivered to the patient was higher (Goldman & Maldjian 2013).

From this findings, it is paramount importance that radiologist and radiographer should apply radiation dose optimization in the CT protocols while performing CT examinations regardless of any MSCT scanners. Although there was no significant difference in radiation dose between 160- and 640-slice CT, each parameter used for protocol customization might affecting radiation dose delivery to the patients. Radiation dose optimization protocols such as high pitch technique, lower kVp and using tube current modulation should be always practiced in order to promote low radiation dose in every scan.

The limitation of this study was the time range of the data collected which was only three months. All data for the scan length and radiation dose of the patient were stored in the scanner. Due to limited memory space in the scanner, the data were deleted every two months and thus, only three months of the data were collected. Besides, only adult subjects were evaluated and pediatric patients were not included in this study. Therefore, results of our study may not apply to pediatric patients. Other limitation in this study was the cases for CT Calcium Scoring, CT Guided Biopsy, CT Angiogram (CTA) and CT multi-phases procedure were not available and hence, the corresponding data were not evaluated and compared.

CONCLUSION

In conclusion, there was no significant difference in the radiation dose between 640-slices and 160-slices CT scanner. Significant difference was observed in SSDE, however, it was due to the presence of body size variation among the study population. Furthermore, this study also showed that there was no significant difference in radiation dose and scan length between genders, but the radiation protection for different genders still need to be emphasized due to the presence of different radiosensitivity among genders.

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