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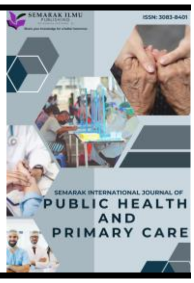

Comparison between Size-Specific Dose Estimate (SSDE) Based on Water Equivalent Diameter and Effective Dose in Adult Computed Tomography (CT) Thorax, Abdomen and Pelvis (TAP)

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ABSTRACT

Computed Tomography (CT) scan examination the most predominant source of medical radiation exposure towards patients globally contributing to 44% of the global effective radiation dose. In Malaysia, the prevalent usage of CT scans to aid diagnostic procedures among patients have raised concerns about the impacts of increasing use of ionizing radiation for diagnosis. This study compares the patient effective dose (ED) and the patient size specific dose estimate based on water equivalent diameter (SSDE Dw) in CT Thorax-Abdomen-Pelvis (TAP) procedure.A prospective study was conducted at a hospital in Wilayah Persekutuan Kuala Lumpur. The study utilized the 128-slice Siemens SOMATOM Definition Dual Source CT scanner. Study parameters of: CTDIvol, DLP, patient antero-posterior (AP) and lateral (LAT) diameter were retrieved from Picture Archiving and Communications System (PACS) for calculations of patient effective diameter, effective dose and SSDE Dw for each respective patient involved in the study. The data obtained were numerically coded and analyzed using SPSS version 29 for Windows 11. Independent T-Test was employed to compare the difference between the means of patient effective dose and SSDE Dw.The results revealed a significant difference between values of patient effective dose and SSDE Dw among patients undergoing CT TAP procedure. The calculated patient effective dose for CT TAP imaging procedure were 11.15 ± 3.3 mSv. The SSDE Dw values in patients who underwent CT TAP imaging procedure were 16.54 ± 3.2 mGy.The radiation dose calculation purely based on effective dose for CT TAP procedure will result in underestimation of patient radiation dose as compared to calculation of patient radiation dose using SSDE Dw. Future study should consider a larger sample size with inclusion of multiple healthcare institutions around Malaysia and a more advance and accurate calculation method for patient radiation dose.

1. Introduction

In Malaysia, ionizing radiation exposure for the purpose of medical examinations is the most predominant artificial source of ionizing radiation that is encountered by the general public.

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According to a 2010 report by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) [1], the radiation dose in Computed Tomography scan studies is indicated to have a contribution percentage of 44% to the global effective radiation dose and thus making Computed Tomography scan examination the most predominant source of medical radiation exposure towards patients. These radiology examinations are vital for diagnostic purposes, which necessitates the use of ionizing radiation, thereby becomes a substantial contribution towards the overall public radiation exposure levels. Despite the generally low dosage of radiation that is administered towards the patients during these procedures, the downside of widespread adoption of ionizing radiation in medical practices is outweighed by its significant impact on the improvement of the public health level and enhancement towards the overall patient care experience.

Computed Tomography (CT) is a diagnostic imaging procedure that has wide utilization within the field of clinical use and research in order to facilitate in the detection of diseases. Unlike conventional radiography, CT imaging has the capability of generating 3 dimensional images of the human anatomy with high resolution and perform multiplanar reconstruction of the resultant image, resulting in CT becoming the preferred tool for diagnosis. Research by Orman *et al.,* [2] found that CT procedures have a high sensitivity and specificity which allows for better detection of diseases which aids in the diagnosis process for various medical disciplines. Despite these advantages, CT scan exposes a higher dose of radiation towards the patient as compared to the delivered radiation dose towards patients in other imaging modalities such as general x-ray and fluoroscopy examinations. There is a huge concern over the amount of radiation dose that is delivered to patients in a CT scan procedure.

Size Specific Dose Estimate (SSDE) is a statistical analysis that can be used to calculate an estimation of the patient radiation dose with consideration of the patient anatomical dimension taken into account and SSDE has been utilized in multiple previous studies to calculate radiation dosage for patient with varying body habitus. Water equivalent diameter (Dw) is the measurement of the diameter of an individual patient's physical dimensions and the estimation of x-ray attenuation in patient expressed as a water cylinder with the same x-ray absorption. The estimation of effective dose (ED) for patients that are undergoing CT imaging procedures are commonly conducted using dose length product (DLP) to effective dose (ED) conversion factors, which are also known as *k*-factors. These *k*-factors were derived from computational human phantoms that are coupled with the Monte Carlo simulations of CT X-ray beams. This upward trend of CT scan utilization highlights the urgent need for understanding of the amount of radiation that a patient receives while undergoing a CT scan procedure.

Numerous studies have highlighted the patient radiation dose of CT TAP procedure. For example, research by Manssor *et al.,* [3] demonstrated there was an increase in radiation dosage by 37, 33 and 43 % as compared to previous studies by Shrimpton *et al.,* [4], Treier *et al.,* [5] and Foley *et al.,* [6], respectively. A study by Quiraishi *et al.,* [7] showed findings where radiation received during an abdominal CT examination logged the maximum radiation organ dose towards organs within the abdominal region due to the multiple radiosensitive organs within the abdominal region. The findings of study done by Quiraishi *et al.,* [7] is also aligned with findings of study done by Lahham *et al.,* [8], where it was concluded that abdominal CT scan accounts for a higher patient radiation dose due to the multiple radiosensitive organs within the abdominal region. Another study performed by Dileto *et al.,* [9], also concluded that the lungs are also radiosensitive organs where despite lung tissue showing absence of symptomatic changes post radiotherapy, a small portion of the thorax will receive some level of pulmonary damage.

Research by Pearce *et al.,* [10] states that overtime exposure towards low levels of stochastic radiation over a person's lifetime shows a direct relationship with the occurrence of cancer and this effect may happen years after exposure. The true risk of low dose radiation exposure from CT scans are uncertain. With the presence of multiple radiosensitive organs within the abdominal region when performing abdominal CT scans, it will be certain that abdominal CT scans will be a higher radiation dose examination for the patients. Patient thickness will also contribute to the fact where there is a risk of patients with higher body mass index receives an increased amount of effective radiation dose towards the patients from performing abdominal CT scan procedures

To measure the approximate radiation dosage that is exposed towards the patients that underwent CT imaging studies of the thorax, abdomen and pelvis region, this study is designed to compare the patient Effective Dose and SSDE Dw among patients undergoing CT TAP procedure.

2. Methodology

2.1 Study Design

This study was a prospective non-experimental study to compare SSDE based on water equivalent diameter and effective dose among patients undergoing CT TAP examination. The study was conducted in the CT suite of the Radiology department in a hospital in Kuala Lumpur, Wilayah Persekutuan Kuala Lumpur.

Patients between the age of 21 years old until 60 years old who were referred to the CT department of the hospital for a CT diagnostic imaging examination of the thorax, abdomen, and pelvic region were included. The sample size was calculated by Eq. (1). Patients that are below the age of 21 years and above the age of 60 years were excluded to focus mainly on the adult population. Critically ill patients and patients that are wheeled or carried by a stretcher into the department for their examination were also excluded as severe health conditions may impact the study's outcome. Patients who did not receive intravenous or oral contrast media are excluded to ensure all the included patients underwent the same standardized imaging procedures. During the study, a total of 60 patients met the inclusion criteria for participation, 4 patients that were below the age of 21 years old and 8 patients that were above the age of 60 years old were also omitted. 7 patients who had previous experiences with contrast allergy were also removed from the list due to failure to comply with CT contrast study requirements of fasting and did not consume CT contrast allergy premedication that were given, they were also removed from the list of patients involved in the study. The final participant rate was noted at 51.67% (n=31).

$$\text{Sample size} = \frac{{Z_{1-\alpha/2}}^{2}\,p(1-p)}{d^{2}} \tag{1}$$

2.2 Equipment and Data Collection

Patient's information is acquired through the Radiology Information System (RIS). Concurrently, the CT TAP images of the patient is obtained through the Picture Archiving and Communication System (PACS) in order to measure the diameter of patient. The CT scan study was conducted under a standardized imaging protocol with 128-slice Siemens SOMATOM Definition Dual Source scanner that comes equipped with an Automatic Exposure Control (AEC). Each image set, consisting of two images, with longitudinal and transverse view of the lesion, were downloaded in digital format, then displayed digitally to the assessors on tablets. For the CT TAP procedure, the CT scanner was configured with a tube voltage of 120 kVp, a pitch factor of .6, and set scan range to 100 cm. The slice thickness and intervals were again reconstructed at 5 mm intervals. Ultravist 300 mgI/ml was the designated contrast media used for the enhanced CT scans. For CT TAP protocols, 100 ml of contrast agent was administered intravenously at a flow rate of 3.0 ml/s, followed by a 50 ml saline flush at the same flow rate, with a scan delay of 73 seconds.

Calculation of patient effective dose estimation was done by multiplying dose-length-product (DLP) with conversion coefficient factor (E/DLP), *k.* ($\mathrm{mSv} \cdot \mathrm{mGy}^{-1} \cdot \mathrm{cm}^{-1}$) Eq. (2). The DLP value was obtained from the Dose Report of each patient from the CT scanner control console and the *k* factor of 0.015 $\mathrm{mSv} \cdot \mathrm{mGy}^{-1} \cdot \mathrm{cm}^{-1}$ was used for thorax-abdomen-pelvic scan regions, which takes reference from the study done by Boone *et al.,* [11] was utilized (Table 1).

$$\kappa = \frac{E}{DLP} = \frac{E}{CTDIvol\ X\ \iota} \tag{2}$$

Table 1
Conversion factor for estimation of effective dose using dose-length-product [11]

Region of body	K(mSv mSv^{-1} cm^{-1})				
Age	0	1	5	10	Adult
Head and neck	0.013	0.0085	0.0057	0.0042	0.0031
Head	0.011	0.0067	0.0040	0.0032	0.0021
Neck	0.017	0.012	0.011	0.0079	0.0059
Chest	0.039	0.026	0.018	0.013	0.014
Abdomen and pelvis	0.049	0.030	0.020	0.015	0.015
Trunk	0.044	0.028	0.019	0.014	0.015

For the measurement of patient's SSDE (D_w), the measurement of the body diameter in AP and LAT dimensions were required for all patients. The measurement level for CT procedure of the TAP region was marked at the level of the twelfth thoracic vertebrae. The obtained dimensions of the AP and LAT dimensions were then used for calculation to obtain the SSDE Dw, which takes reference from the study done by Mihailidis *et al.,* [12] was utilized. In order to calculate the body dimensions for SSDE Dw, the total length of LAT is calculated using Eq. (3) *where* ρ_e^{lung} = 0.30 is the relative electron density of lung tissue relative to water. The Dw is calculated using Eq. (4). Patient's SSDE (D_w) is then calculated using Eq. (5) which takes reference from study done by Boone *et al.,* [11].

$$LAT_{eff}^{corr} = d_1 + d_{2l}\ X\ \rho_e^{lung} + d_3 + d_{4l}\ X\ \rho_e^{lung} + d_5 \tag{3}$$

$$D_{eff}^{corr} = (D_w) = \sqrt{AP\ X\ LAT_{eff}^{corr}} \tag{4}$$

$$SSDE = f_{size}^{32x}\ X\ CTDI_{vol}^{32x} \tag{5}$$

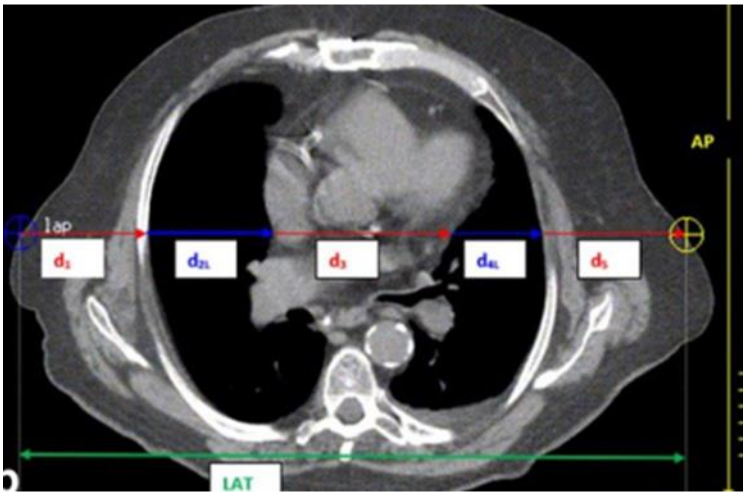

Fig. 1. Parameters for body dimension calculations [12]

2.3 Statistical Analysis

The normality of each data set was determined by using the Shapiro-Wilk test. In order to compare the patient effective dose and SSDE Dw between different patients, an independent t-test was employed to compare the patient ED and SSDE Dw. All of the data were presented in mean ± standard deviation. A threshold for statistical significance was set at a p-value of less than .05. This indicates that differences observed with a p-value below this threshold are considered statistically significant.

3. Results

3.1 Participants' Demographics

Participants' demographics was summarised and presented in Table 2 below. The study sampled 100% (n=31) of the patients. The majority of the patients were male 52% (n=16) and 48% (n=15) were female patients. 45% (n=14) of patients accounts for Chinese which is the highest number of patients who underwent CT TAP examination followed by Malay 35% (n=11) and Indian 20% (n=6) respectively. There were four age ranges included in the study. Out of the four, age range 41-50 were noted as the highest at 56% (n=17) with second highest age range of 31-40 at 26% (n= 8). The least number of patients were in the age ranges of 21-30 and 51-60 with both age ranges at 9% (n=3). The study sampled 100% (n=31) of the patients. The majority of the patients were male 52% (n=16) and 48% (n=15) were female patients. 45% (n=14) of patients accounts for Chinese which is the highest number of patients who underwent CT TAP examination followed by Malay 35% (n=11) and Indian 20% (n=6) respectively. There were four age ranges included in the study. Out of the four, age range 41-50 were noted as the highest at 56% (n=17) with second highest age range of 31-40 at 26% (n= 8). The least number of patients were in the age ranges of 21-30 and 51-60 with both age ranges at 9% (n=3).

Table 2
Participants' demographics

Variable	Frequency	Percentage, %
Gender		
Male	16	52
Female	15	48
Ethnicity		
Malay	11	35
Chinese	14	45
Indian	6	20
Age range		
21 – 30	3	9
31 – 40	8	26
41 – 50	17	56
51 – 60	3	9

3.2 CT Dose Parameters for CT TAP Procedure

Patient CT Dose Parameters for CT TAP procedure based on 32 cm Diameter PMMA Phantom was obtained from PACS. The parameters retrieved were mainly the CTDIvol, DLP and Scan Length values for each patient. These values are used for the calculations of Patient ED and Patient SSDE Dw. In general, the average scan length for CT TAP procedure were 56.2 ± 12.89 cm. The average DLPs obtained for CT TAP examination were 743.15 ± 220.24 mGy.cm.

3.2.1 Patient effective radiation dose and SSDE Dw

The calculated patient ED for CT TAP imaging procedure were 11.15 ± 3.3 mSv. The SSDE Dw values in patients that underwent CT TAP imaging procedure were 16.54 ± 3.2 mGy. The The t-statistic is 6.528, and the p-value is less than 0.001, indicating a statistically significant difference between the means of Effective Dose and SSDE Dw.

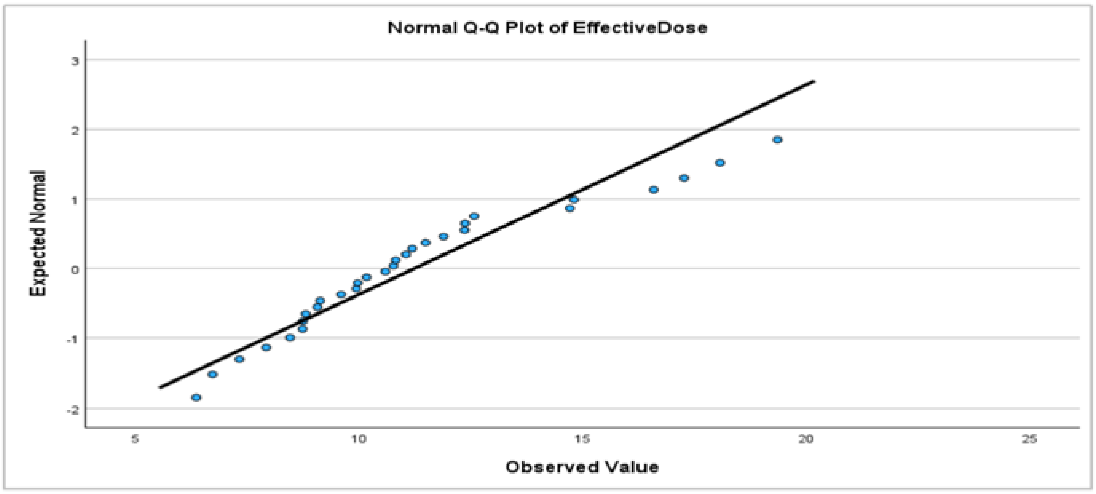

Fig. 2. Normality test Q-Q plot of effective dose

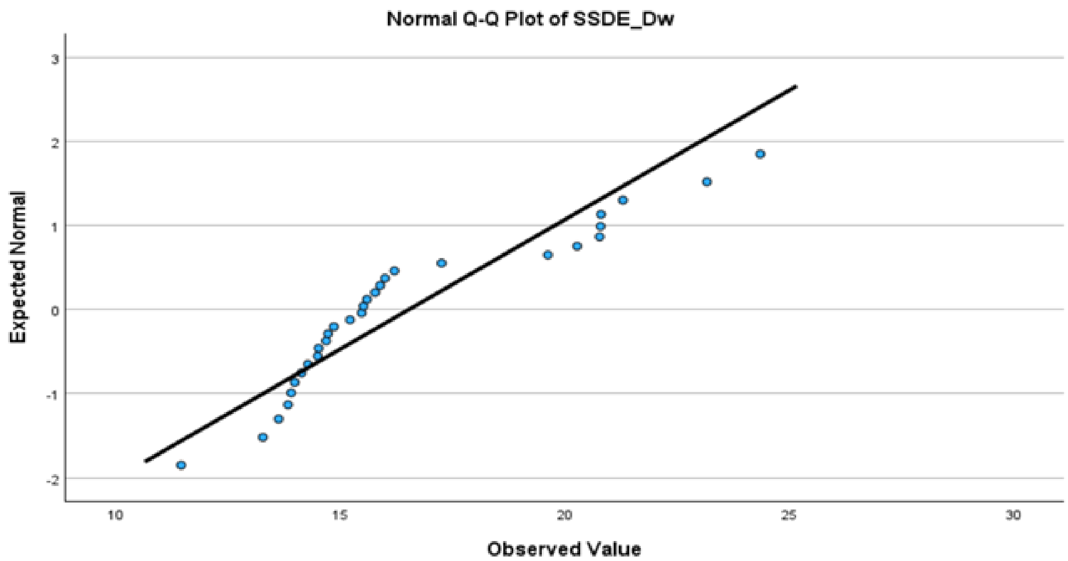

Fig. 3. Normality test Q-Q Plot of SSDE Dw

4. Discussion

4.1 Prevalence of CT Imaging Procedure for Diagnosis in Malaysia

The popularity of CT imaging procedure as the main radiological examination has risen tremendously, establishing itself as a dominant imaging modality that is frequently used in radiological examinations across the globe. The College of Radiology, Academy of Medicine of Malaysia [13] has previously expressed concerns about the escalating usage of CT scans, particularly regarding the practice of performing whole-body CT screening scans among Malaysian patients. This raises concerns towards the cumulative radiation exposure towards the Malaysian population. If the utilization of CT imaging procedure is left unsupervised, it could pose a serious health risk towards patients where the risk outweighs the potential benefits to patients that underwent whole body CT scan screening.

A study by Fadzli *et al.,* [14] shows that CT scans, MRI scans, and general radiography have more than 12 hours of utilization during a 24-hour cycle hospital operational period. This indicates that there is a heavy reliance on CT scans not only as a radiological imaging modality but also signifies the increasing importance of CT in elective and emergency interventional radiological services resulting in a growing workload. The increasing usage of CT scan examinations may infer that there is a greater risk towards patients undergoing medical radiological examinations, given that ionizing radiation is used during the CT scan examinations.

4.2 Comparison of Radiation Parameters

4.2.1 Dose length product

Study by Arfat *et al.,* [15] states that DLP is a radiation dose parameter that describes the amount of radiation dose that is given to the patient for a complete CT examination in order to estimate the potential biological effect the given radiation may have on the patient. DLP in mGy.cm can be calculated by multiplying the CT Dose Index (CTDIvol) in mGy with the total scan length of the CT examination in cm. However, the findings of DLP in our study does not match up when the results of CTDIvol and scan length was multiplied, the observed findings from the study shown that the value of DLP obtained from CT TAP examinations was greater than the product of CTDIvol and scan length.

According to study performed by Booij *et al.,* [16], the observed phenomena was a result of over ranging effect. Over ranging effect is the primary radiation that is delivered to the patient outside of the imaged volume. Spiral CT with its superior imaging capabilities and efficiency poses significant advantages over sequential CT scanners in clinical applications. However, one of the drawbacks of Spiral CT is the increased occurrence of over ranging effect due to the use of wider detector array and higher pitch settings used in Spiral CT scanners. The over ranging effect results in an elevation in the patient radiation dose as additional primary radiation is delivered to areas of the patient's body that lies outside of the intended imaging volume in a CT examination. This observed over ranging phenomenon affects all of the CT radiation dose results in our study due to the fact that the estimation of patient radiation dose by multiplication of the obtained CTDIvol value with the scan length will only result in an under estimation of the total DLP given towards the patients.

The obtained DLP values were compared with the national Diagnostic Reference Level (DRL) for CT TAP. The average DLPs obtained for CT TAP examination in our study were 743.15 ± 220.24 mGy.cm, which is lower than the national DRL value of 1600 mGy.cm by the Ministry of Health Malaysia (MOH 2013) as well as DRL that is published for other countries such as Egypt (1320 mGy.cm), Ireland (850 mGy.cm), Greece (1020 mGy.cm), Japan (1300 mGy.cm), and Institutional DLR for National University Hospital in Singapore (1090 mGy.cm) [17,18].

4.2.2 Effective dose

In order to assess the risk profile for a CT examination protocol, the relevant dose metric that is taken into consideration is ED. ED from CT examinations depends on multiple factors such as CT scanner type, exposure parameters used during scanning, selection of the CT protocol that is used for the examination as well as the body region that is being examined. A study by Ali [19] in 2005 indicated that the mean patient ED from CT abdominal examinations were about 10 mSv. The National Radiological Protection Board 1992 report [20] also stated that it is estimated that 10 mSv effective radiation dosage may cause an increase in the lifetime risk of a fatal cancer by 1 in 2000.

A cohort study by Smith-Bindman *et al.,* [21] has revealed that the mean effective dose for a routine CT combined chest and abdominal examination in various countries around the globe. The reference patient effective dose per CT examination was 13.7 mSv, ranging from 6.0 – 27.4 mSv (UNSCEAR 2000 report). The highest patient ED is from Japan with 37.9 mSv and Israel at 23.7 mSv. Our study has revealed that the mean effective dose for CT TAP examination in Malaysia was 11.15 ± 3.3 mSv. Therefore, it can be derived from the results obtained from the study that the mean effective dose for CT TAP examination is 0.8 times that of the global reference mean effective dose per examination that is recommended by UNSCEAR. However, the results of this study may not be applicable to form a generalized conclusion for the entirety of the Malaysian population that underwent CT TAP examinations due to the fact that the information for patients examined annually was not collected and the data collection for patient information was confined to a single hospital only.

The differences in the value of effective dose among patients that underwent CT TAP procedure between countries may be a result of the types of CT scanner that is employed during the examination procedure such as spiral CT, single slice CT (SSCT), multi-slice CT (MSCT), and non-spiral CT scanners. The study by Ali [19] was also able to analyse the differences in effective dose among patients undergoing CT examinations and was able to come up with the calculations where non-spiral CT scanners have a higher effective dose among patients by a factor of 1.3 as compared to patients that underwent CT examinations using Spiral CT scanners. Although studies found that the effective dose value of patients undergoing CT examinations differ when using different types of CT scanner, the current study did not attempt to differentiate the patient effective dose for different types of scanners used.

4.2.3 Size specific dose estimate

SSDE Dw is a patient radiation dosage estimation that takes into accounts for the correctional factors that are based on the body dimensions of patients by calculating the effective diameter of the patient body dimensions with consideration of the relative electron density of the tissues within the scan region of the CT imaging examination.

In order to evaluate the results that are obtained from our study, a comparison of the SSDE values was done with the results of other studies. In our study, the value of SSDE Dw among patients undergoing CT TAP procedure was calculated as 16.54 ± 3.2 mGy. According to the instructions in the American Association of Physicists in Medicine report 204 [22], the mean SSDE reference level for CT TAP imaging studies is 11.31 mGy. Studies by Choudhary *et al.,* [23] and El Mansouri *et al.,* [24], have revealed that the SSDE of patients undergoing CT TAP examinations in their respective countries (India at 20.1 mGy; Morocco at 12.15 mGy).

The SSDE values obtained from the current study has comparable results with the SSDE values reported from previous studies conducted by AAPM and researchers in Morocco. However, there are some notable differences in the methodology and the results obtained by El Mansouri *et al.,* [24]. In El Mansouri's research, CT scan examinations were performed without the use of contrast medium, even though the same CT scanning protocol as our study was applied. This difference in approach in study methodology may have contributed to slight variations in SSDE values observed as compared to our study where the CT scan is performed with the use of contrast media. The observed differences in the values of SSDE between this study and other referenced studies may also be a result of the variations in mAs applied during the scanning process. This is due to the differences in patient size across the various countries and region across studies as well as the usage of fixed exposure settings in the CT scanning protocol instead of Automatic Tube Current Modulation (ATCM) settings by CT scanner in our study. The ACTM technique was not applied in our study as this study was performed using a fixed exposure setting CT TAP protocol. Studies by Schindera *et al.,* [25] and Christner *et al.,* [26] has investigated the correlation between patient radiation dose and patient size and the outcomes of these studies all suggest that there is an apparent increase in the radiation dosage that is administered to the patient's organs as patient size increases with the main attribution cause being the Automatic Exposure Control (AEC) system. The study by Schindera *et al.,* [26] also found that patients with a larger body habitus were found to have received a higher radiation dose in the CT scanning examinations with ATCM compared to patients who had a smaller body habitus due to the fact that a higher tube output was required by the CT scanner to achieve the desired image quality without sacrificing diagnostic quality of the image.

4.3 Optimization of Radiation Dose

In conjunction with the increased usage of CT as an imaging modality, there is also a rise in concerns about the potential radiation hazards towards patients undergoing CT examinations. In order to deal with such concerns around the world, various CT dose reduction and optimization strategies have been developed in order to maximize the benefit to risk ratio of CT examinations towards patients undergoing such examinations. This is due to the fact that each radiological exposure involves an interaction between the exposed body tissues with ionizing radiation which may potentially result in a permanent change in the cellular gene structure causing tumour formation and hereditable effects towards the patient involved in the CT examination.

There is a need to reinforce the importance of adherence to International Commission on Radiological Protection (IRCP) principles of justification and optimization (IRCP 2007) among those involved in the diagnosis and treatment process [27]. In order to be compliant with the ALARA principle, it is of utmost importance that CT examinations that patients will undergo is justified beforehand. Radiologists plays an important role as an advisor and gatekeeper to the use of ionizing radiation as a tool for medical imaging procedure. They need to be familiar with the concept of tailoring medical imaging procedures suited for each specific patient diagnosis and indication.

In order to be able to reduce and optimize the amount of patient radiation dosage during CT examinations, there is a need to understand all the dose parameters that may influence the amount of radiation dose given towards patients during a CT examination. This is due to the fact that the dose parameters in CT scanners are initially set up by the manufacturer of the CT scanner, which may have put a higher emphasis on delivering medical images of higher quality instead of radiation dose optimization in clinical application settings. This technique is known as body size adapted CT Protocol and it is a fundamental part in the optimization of CT radiation dose as the minimum radiation dose that is required by each individual patient while maintaining high diagnostic image quality varies depending on patient body size and body habitus.

According to Trattner *et al.,* [28], usage of optimal scan parameters and technologies can be of aid in the goal of optimizing and reduction of radiation dose for CT examinations. The study recommends the use of 120 kVp or lower kVp CT protocols for routine scanning of the abdominal region except for patients that are morbidly obese. The study also suggests the use of a wider CT detector configuration and non-overlapping pitch in order to maximize the scanner radiation dose efficiency which may reduce the amount of radiation dose delivered to patients undergoing CT examinations.

Studies performed by Kalra *et al.,* [29] and Singh *et al.,* [30] has proven that iterative reconstruction processing algorithms and programmes are able to reduce image noise as compared to standard filtered back projection reconstruction techniques, therefore allowing for CT scan examinations to be performed at a much lower radiation dose amount. This is mainly due to the fact that the conventional noise-reduction filters decrease image noise but simultaneously decreases the image contrast which lowers the diagnostic value of the reconstructed CT image. Modern iterative reconstruction processing algorithms are also able to aid in reduction of resultant image noise and improve the rate of acceptability of lower kVp images without sacrificing the diagnostic value of the reconstructed CT image while having a higher reconstruction speed as compared to the conventional filtered back projection reconstruction filters.

4.4 Limitations of the Study

Despite its contributions, this study has several limitations that must be acknowledged. The study was conducted was confined within a specific region, therefore potentially limiting the generalizability of the results and findings to the entire Malaysian population. The differences in the demographic, access to healthcare, socioeconomic factors, and even regional practices in medical imaging procedure that are unique to the study region may introduce a degree of specificity that necessitates cautious interpretation when attempting to extrapolate the findings to a more broad and diverse population.

Another significant limitation that is identified in the study relates to the time frame that is allocated for data collection. The entire data collection process for the entirety of this study was confined to a relatively short period of three months. While the data obtained is prospective in nature and utilizes random sampling method in data collection, it is still susceptible to inherent biases that may affect the result of study due to the short timeframe and variability of patient characteristic. The condensed time frame for this study may result in a result that do not fully reflect the variations of population that is under study. The short duration of data collection process may also limit the ability of the study to observe the effects of changes and trends of healthcare guidelines or technology in patient radiation dose.

The patient inclusion criteria in this study represented another significant limitation of the study whereby only adult patients between the ages of 21 years old to 60 years old were evaluated. By excluding both the Paediatric and Geriatric population, the results of the study restrict its applicability to patients of both of these population. Paediatric patients who are more radiosensitive due to developing tissues, and Geriatric patients who may have pre-existing conditions represents distinct patient categories with unique physiological and clinical considerations which may affect the patient radiation dose from undergoing CT examinations. The exclusion of these groups limits the generalizability of the study findings and also loses the opportunity to understand how CT imaging parameters might affect the radiation dose towards patients.

4.5 Recommendations

To address the limitations identified in this study and improve the generalizability of future research, the following recommendations are proposed.

A more extensive study by using a larger sample size for CT TAP scanning procedures and include data from multiple healthcare institution, combined with a longer period of data collection spanning several months or years would lead to a more robust amount of patient radiation dosage data, enhancing the reliability and applicability of the findings towards the general population of Malaysia. could be performed having a larger sample size allows for facilitation of a better comparison results of radiation dose indices with diverse patient demographic and clinical practices which ensures a broader applicability and generalizability of the findings from the study. Having a larger patient sample size also allows for better differentiation amongst certain age categories for paediatric, adult and geriatric patients. This will allow for a better estimation of how radiation dose varies within certain age groups. This allows the results of the study to be able to be applied more broadly across patient populations which can aid in the diagnosis and treatment planning of patients when using CT scan as the main imaging modality. A longer duration of research study may also provide insights on how the development of CT scanner technology as well as improvements of radiological guideline standards may affect the cumulative medical radiation dosage for patients undergoing CT imaging examinations.

More accurate measuring techniques to determine the SSDE Dw can be used when obtaining data for a larger sample size of patients. For instance, the usage of computational slice-by-slice calculation application for SSDE used by AAPM Task Group 220 [23], which takes into account the use of 16cm or 32cm diameter dose index phantom and patient size-specific conversion factor respectively and their relationships for each type of phantom used. Doing this will allow for a more precise and accurate calculated result of patient SSDE Dw as compared to the manual calculation method to estimate patient Effective Diameter and patient SSDE Dw.

The importance of prioritizing education and professional development among radiographers should not be understated, particularly in Malaysia where the demand for advanced radiological procedure continues to rise. Given the inherent risks associated with the use of ionizing radiation during CT examinations, it is of utmost importance that radiographers are equipped with knowledge and skills to handle new CT technologies safely and effectively. By emphasizing continuous professional development and standardization, radiographers will play an important role in minimizing patient risk while providing the highest quality of diagnostic imaging.

5. Conclusion

This study offers crucial insights into the radiation doses that patients will receive during CT TAP imaging procedure and the study findings may be used as a reference in future studies to establish a DRL to assist in optimization of patient radiation dosage for CT TAP examinations in Malaysian healthcare settings in order to enhance patient safety through a more judicious use of radiation in healthcare centres in Malaysia. Ultimately, this study hopes to provide medical professionals with valuable data to inform their clinical decisions by understanding the balance between diagnostic benefits and radiation risk towards their patients therefore ensuring patients receives the most appropriate imaging study for their condition while minimizing unnecessary radiation exposure without compromising the quality of diagnostic imaging and promoting a more efficient and effective use of CT imaging examination in clinical practice.

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