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RESEARCH ARTICLE

Diagnostic reference level for computed tomography thorax examination: A single centre study

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Abstract:

The increased number of CT Thorax examinations has shown an increase in frequency of patients exposed to medical radiation. Therefore, the recent radiation exposure from CT thorax should be revised to achieve dose optimization. This study aimed to determine a local diagnostic reference level (DRL) in CT thorax study. Data on CT thorax cases (n=307) were retrieved retrospectively from the Picture Archiving Communication System (PACS). Data input including CT scanner model, manufacturer and scanning parameters were incorporated in the CT-EXPO software. Weighted CT dose index ($CTDI_w$), volume CT dose index ($CTDI_{vol}$), dose length product (DLP) and effective dose (E) were automatically generated from the input. The data was presented as 75th percentile and compared with the previous established national DRL report from the Ministry of Health Malaysia. The results demonstrated DRLs of $CTDI_w$, CTD_{vol}, E and DLP are significantly lower than the established national DRLs ($p < 0.001$ and $p = 0.011$, respectively) with reduction of 62.2%, 62.2%, 32.6% and 5.5%, respectively. The dose variations between local and national DRL may suggest for dose optimization in CT thorax examination.

Keywords: CT dose index, CT thorax**,** diagnostic reference level, dose length product, effective dose

1. INTRODUCTION

Computed Tomography (CT) has become a very essential diagnostic imaging tool in many clinical settings due its cross-sectional imaging capabilities, high temporal and spatial resolution, and excellent anatomical details (Brenner & Hall, 2007). The highly expanded use of CT scan procedures has increased the contribution of CT radiation dose to the patient population. Radiation dose of CT scan has been linked to cause severe deterministic effect as well as stochastic effect due to unoptimized practiced delivered (Hoang et al., 2015). Substantially high doses from routine CT examinations (head, chest and abdomen) and dose variations within and between radiology facilities have been reported in the literatures (Koller et al., 2003; Smith-Bindman et al., 2015).

In 1990, the International Commission for Radiological Protection (ICRP) introduced “diagnostic reference level” (DRL) to encourage authorities, governing bodies and health institutions in medical practice to establish safety standards for radiation exposure that conform to clinical purposes (International Commission on Radiological Protection, 2007). DRLs are designed to represent the safety reference of radiological procedures for a local centre, specific region or even nation. The derivation of DRLs allows the institution to control the use of radiological procedures in a way that suits health needs and eliminates undesired exposure without compromising image quality ref. Generally, the DRLs are usually set to the 75th percentile (third quartile) of the national dose apportioning ever since it was first established by the ICRP in 1996. Standardized CT measurements used to set up DRLs are the volume CT dose index ($CTDI_{vol}$) and dose-length product (DLP) (Korir et al., 2015; Journy et al., 2017). CT Regulatory bodies may determine a national DRL from wide-ranging surveys at hospitals in a region or country (Karim et al., 2016; Salaama et al., 2017). This study is aimed to determine a local DRL in CT thorax study and compare the present findings with the previous established national DRL report.

2. MATERIALS AND METHODS

2.1 Sampling and CT Thorax Protocol

Data on CT thorax cases (n=307) from January to March 2020 were retrieved retrospectively from the Department of

Radiology, Hospital Serdang using the Picture Archiving Communication System (PACS). Prior data retrieval, permission for data collection has been granted from the hospital authority and department. As Hospital Serdang is one of the public hospitals in Selangor which has high volume of CT examinations particularly in CT thorax study, this factor was taken into consideration as the current study population. The CT procedures were acquired using Siemens SOMATOM Dual-Source Definition Flash 128 MDCT. The CT scanning protocol was acquired using the following parameters: tube output (80 – 40 kV), tube current (84 - 365 mAs), pitch (0.8), collimator/detector selection (128 x 0.6), slice thickness (5 mm) and scan length (205 – 428 cm). The sample size was estimated using online Raosoft sample size calculator. Data of patients over 18 years old and non-contrast CT thorax was included in this study. Subjects with follow-up CT thorax were excluded from the data subjects.

2.2 CT Dose Calculation

Input including scanner model, manufacturer and scanning parameters (kV, mAs, N*hcol, pitch and scan length) were incorporated in the CT-EXPO software Version 2.5 (Sascrad, Berlin, Germany) as shown in Figure 1. CT-EXPO software is a preferable tool for CT dose estimation as has advantages of dose calculation for all age groups, gender and all existing scanner models, and correction of scanner-specific influences as well (Stamm & Nagel, 2014). The software was used for automated dose calculation. The auto-generated weighted CT dose index ($CTDI_w$), volume CT dose index ($CTDI_{vol}$), dose length product (DLP) and effective dose (E) values were recorded. The E was calculated based on the tissue weighting factor published in ICRP 103 (International Commission on Radiological Protection, 2007).

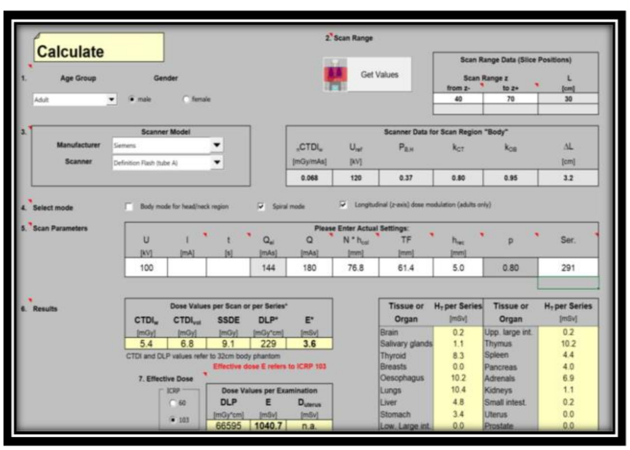

Figure 1. Data input in CT-Expo version 2.5

2.4. Data Analysis

Data were presented descriptively as mean ± standard deviation (SD) using the 75th percentile and compared with the previous established national DRL report (Ministry of Malaysia, 2009) using One Sample T-test. The statistical analysis was performed using SPSS Version 25.0 (IBM Corporation, Armonk, NY, USA).

3. RESULTS AND DISCUSSION

A total of 177 (42.53%) male and 131 (57.47%) female patients with the mean age of 50 ± 10.3 years old were included in this study. The third quartile (75th percentile) values of $CTDI_w$, $CTDI_{vol}$, DLP and E acquired from the present study and national DRL are shown in Table 1. The result shows the present DRL is significantly lower than the established national DRL ($CTDI_w$, $CTDI_{vol}$ and E, $p < 0.001$; DLP, $p = 0.011$).

Table 1. Third quartile (75th percentile) of $CTDI_w$, $CTDI_{vol}$, DLP and E from the present study and national DRL

CT dose parameter	Present study	National DRL (MOH, 2013)	p-value
$CTDI_w$ (mGy)	8.05 ± 3.29	21.30	< 0.001
CTD_{vol} (mGy)	10.06 ± 4.11	26.63	< 0.001
DLP (mGy.cm)	392.31 ± 155.91	415.00	0.011
E (mSv)	5.39 ± 2.21	8.00	< 0.001

The DRL of this study shows a reduction of 62.2%, 62.22%, 5.5% and 32.6% in $CTDI_w$, $CTDI_{vol}$, DLP and E, respectively as compared to the respective national DRL. This variance could be due to scanning protocols and CT scanner model used for CT thorax examinations (Dougeni et al. 2012). All CT thorax examinations have been performed using spiral scanning mode acquisition in Hospital Serdang. A dose reduction of 3% - 14% could be achieved by using spiral scanning mode (Ekpo et al., 2018).

Both developed and developing countries have established dose survey data as a guideline to develop their local DRL in radiological procedures (Anna et al., 2013; Mbolatiana et al., 2015; Kim et al., 2017). A DRL could serve as an important tool in optimizing the CT protocols (Khoramian et al., 2009; Paolicchi et al., 2014; Vassileva, & Rehani, 2015). Historically, the Ministry of Health Malaysia had established its national DRL for radiological procedures in its Medical Radiation Exposure Report in 2009 (Ministry of Health Malaysia, 2009). However, due to rapid advancement of CT technology, it is a necessary to review the current CT protocols to achieve CT optimization. The radiation dose exposure also varied by parameters and protocols, including tube voltage (kVp), effective mAs, pitch and slice thickness (Zarb et al., 2011; Gao et al., 2017; Papadakis & Damilakis, 2019). This contributed to safety concerns as E was a factor in the assessment of the biological effects of radiation on patients (Yuasa et al., 2019).

Furthermore, automatic tube current modulation (SIEMENS CAREDose 4D) has been implemented in our department. Automatic tube current modulation modulates the tube current in real-time according to different attenuation of patient size and patient anatomy to achieve optimization of dose utility. Thus, unnecessary high radiation dose will be eliminated. CAREDose 4D modulates the tube-current in longitudinal (z-axis) and angular direction (x-y plane). The adaption of tube-current is based on image Quality Reference mAs (QR mAs). It is a technique parameter used to determine the desired level of image quality. The outcome of CAREDose 4D is the constancy of image quality with a lower radiation dose (Söderberg & La, 2013).

The established national DRL is a medical radiation exposure study which conducted between 2007 – 2009 and involved 437 public, and private hospitals and general practitioner's clinics as well. The data obtained were mostly from Single Slice Computed Tomography (SSCT) scanner. Importantly, the SSCT scanning does not provide $CTDI_{vol}$ data directly as a CT dose parameter. With the advancement of CT technology over the years and the current practices, most of SSCT scanners have been replaced by Multi Slice Computed Tomography (MSCT) scanner. With taking consideration of the evolution of SSCT to MSCT scanner, $CTDI_{vol}$ is currently employed as an alternative dose descriptor to represent DRL instead of $CTDI_{w}$ ref. Interestingly, the present study reported the local DRL of CT thorax using dual-source CT (DSCT) which has not been reported extensively. The utilization of DSCT is another potential factor contributing for CT dose reduction in the present study which is in accordance with the previous literatures (Forte et al., 2018; Canellas et al.; 2018; Lenga et al., 2019)

This study had several limitations. The estimated results were collected from single institution using single scanner model and only involved adult data. Therefore, the results could not be generalised to the whole Malaysian population. Future studies could consider paediatric patients as an extra cohort and increase the number of healthcare institutions using various scanner models.

4. CONCLUSION

To conclude, the local DRL of CT thorax is lower than the established national DRL. DRL is recognized as an important tool in optimizing radiation dose for patients according to the As Low as Reasonably Achievable (ALARA) principle. Hence, the established data on the dose reference level in this study could contribute as a guideline for dose optimization in CT thorax examination.

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