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Radiation doses from computed tomography practice in Johor Bahru, Malaysia

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HIGHLIGHTS

- We investigate radiation doses received by patients from CT scan examinations.
- We compare data with current national diagnostic reference levels and other references.
- Radiation doses from CT were influenced by CT parameter, scanning techniques and patient characteristics.

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ABSTRACT

Radiation doses for Computed Tomography (CT) procedures have been reported, encompassing a total of 376 CT examinations conducted in one oncology centre (Hospital Sultan Ismail) and three diagnostic imaging departments (Hospital Sultanah Aminah, Hospital Permai and Hospital Sultan Ismail) at Johor hospital's. In each case, dose evaluations were supported by data from patient questionnaires. Each CT examination and radiation doses were verified using the CT EXPO (Ver. 2.3.1, Germany) simulation software. Results are presented in terms of the weighted computed tomography dose index ($CTDI_w$), dose length product (DLP) and effective dose (*E*). The mean values of $CTDI_w$, DLP and *E* were ranged between 7.6 ± 0.1 to 64.8 ± 16.5 mGy, 170.2 ± 79.2 to 943.3 ± 202.3 mGy cm and 1.6 ± 0.7 to 11.2 ± 6.5 mSv, respectively. Optimization techniques in CT are suggested to remain necessary, with well-trained radiology personnel remaining at the forefront of such efforts.

1. Introduction

Since the introduction in 1972 of x-ray computed tomography (CT) (Jessen et al., 1999), CT patient doses have remained a particular focus of interest, the continuous radiation output along the z-axis during scanning often leading to dose values rather greater than those from many other x- and gamma-ray imaging modalities. With X-ray CT now widely established, the number of examinations using these techniques has rapidly grown, it being noted in an 2008 Report of the United Nations Scientific Committee on the Effects of Atomic Radiations (UNSCEAR) that at the time of the report some 221 million CT examinations were being performed annually world-wide, contributing over 44% of the global collective effective dose equivalent from medical exposures (UNSCEAR, 2010). CT scans are thus recognized to be a high radiation dose modality when compared with other imaging modalities, with the added concern that the doses have sometimes accrued from clinically unjustified use of the modality (Dougeni et al., 2012; Holmberg et al., 2010; McCollough et al., 2009).

With the various dose dependencies in mind, optimization techniques to reduce the dose to the patients, especially in regard to paediatric cases remains a popular focus of efforts (see for instance, Muhogora et al., 2006; Suliman et al., 2011). Of importance in recognizing such endeavours is that by far the majority of these have arisen in the developed world, a clear reflection of the high levels of awareness of the benefits versus risks of advanced technology within such societies. This is not to deny that there exist examples elsewhere of major efforts towards developing dose controls, including the example of Malaysia where economic

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circumstances has lead to massive introduction of high-end medical diagnostic systems. Thus to ensure that diagnostic doses are optimized and in line with the concept of ALARA, numbers of regulatory agencies have established diagnostic reference levels (DRLs), including those from use of CT (Foley et al., 2012; Ministry of Health Malaysia, 2013a; Muhogora et al., 2008; Shrimpton et al., 2006).

With input available from dose surveys, DRLs continue to be regularly reviewed including those due to CT devices (Muhogora et al., 2006; Pantos et al., 2011; Shrimpton et al., 2006; Suliman et al., 2011), forming part of a continuing effort to maintain dose-efficiency from firmly established as well as state-of-the-art developments in radiological imaging practice.

In clinical practice, radiation dose from CT needs to be closely monitored and managed, giving access to data from which scanning protocols and associated doses can be optimized (Muhogora et al., 2006; Rehani, 2012; UNSCEAR, 2010). Typically, three types of CT dose descriptor are used in indicating diagnostic reference levels (DRLs): weighted computed tomography dose index ($CTDI_w$), dose length product (DLP) and effective dose (ICRP, 1996). These descriptors link to factors contributing to dose, primarily scanner output, scan protocols and patient characteristics (Christner et al., 2010), noting also that radiation doses from the same type of CT scanner will vary from one machine to another (Muhogora et al., 2006), variations that also encompass technique and clinical practice (Suliman et al., 2011).

In 2013, based on a survey study conducted over the period 2007 to 2009, Ministry of Health of Malaysia (MOH) regulations introduced National Diagnostic Reference Levels (NDRLs), the purpose being to more closely monitor and control radiation doses from the various imaging modalities. Table 1 shows the NDRLs for CT examinations (Ministry of Health Malaysia, 2013a, 2013b). Hence, the purpose of the current work is to help to provide baseline study data to feed into such efforts. The outcome will establish the radiation doses data from the CT patients in developing countries (Muhogora et al., 2008; Rehani, 2012; Rehani et al., 2012).

In response to this, the present study has sought to provide a situation analysis for current doses in CT practice in Johor Bahru and to compare these against current NDRLs and others relevant references.

2. Materials and methods

2.1. Dose survey

In this study, a set of questionnaires were prepared for four centres conducting CT procedures in Johor Bahru, the state capital of Johor in southern Malaysia. Specifically, the four centres were: Department of Radiology, Hospital Sultanah Aminah Johor Bahru (HSAJB); Department of Radiology, Hospital Sultan Ismail Johor Bahru (HSIJB); Oncology Centre, Hospital Sultan Ismail Johor Bahru (HSIJB-R) and Department of Radiology, Permai Psychiatric Hospital (HPER). Details of the facilities are shown in Table 2.

Table 1
National Diagnostic Reference Levels for Malaysia country.

Examination type	DRLs in CTDIw (mGy)	DRLs in DLP (mGy cm)
Abdomen	12.8	450
Brain	46.8	1050
Cardiac	11.8	870
Chest	19.9	600
Pelvis	39.1	730
Spine/Musculo-skeletal	16.3	390
Others	12.3	380

Table 2
Sampling sites and scanners included in the study.

Hospital	CT scanner			
	Manufacturer	Brand	Detector configuration	Year of installation
HSAJB	Siemens	*Definition AS Plus*	64 × 2 slice (MSCT)	2010
HSIJB	Siemens	*Somatom Emotion Duo*	Dual slice (DSCT)	2004
HPER	Siemens	*Somatom Emotion 16*	16-slice (MSCT)	2010
HSIJB-R	Siemens	*Somatom Emotion*	Single slice (SSCT)	2004

In accordance with the approach used elsewhere, the questionnaires were completed by personnel directly connected with operation of each facility (Brix et al., 2003; Muhogora et al., 2006; Shrimpton et al., 2006; Suliman et al., 2011). Prior briefing was carried out to ensure meaningful returns, the data requested being:

i. Name of Hospital, manufacturer and type of scanner(s).
ii. Case ID and examination type.
iii. Patient characteristics: Ethnicity (Malay/Chinese/Indian/Others), Gender, Age, Weight, Height and Body-Mass Index (BMI).
iv. CT parameters: tube potential (kV), tube current (mA), time (s), effective tube current (mA s), nominal collimation beam width (N^*h_{col}), table feed, slice thickness and scan range.
v. Radiation output from the displayed console, including volume Computed Tomography Dose Index (CTDI) or weighted CTDI ($CTDI_{vol}/CTDI_w$), dose length product (DLP), total mA s and for CT of the brain / head, the angle of tilt of the gantry, in degrees.
vi. Number within the series for any contrast study or other imaging sequence.

It is noted that all of the CT scanners included in Table 2 are subject to Planned and Preventive Maintenance (PPM) and have all passed the annual quality assurance (QA) carried out by consultant physicists. It can therefore be assumed that all of the scanners were performing optimally. Resulting from a two month period of measurements, the results encompass data for 376 patients, for various CT examinations that included brain, cervical spine, chest, abdomen, pelvis and whole trunk.

2.2. Dosimetry in computed tomography

CTDI, the principal dosimetry in CT, is a standardized measurement of radiation output of CT units, derived from the dose distribution along a line parallel to the axis of rotation for the scanner (z-axis), recorded for a single rotation of the x-ray source. According to the International Commission on Radiations Unit and Measurements (ICRU) report no.87, CTDI is defined as (ICRU, 2012):

$$CTDI_\infty = \frac{1}{nT}\int_{-\infty}^{\infty} K(z)dz, \tag{1}$$

where, $K(z)$ is the air kerma in the phantom as a function of position at a given location, z, n is the number of tomographic sections imaged in a single axial scan and T is the nominal width of the tomographic section along the centre of the z-axis. By integrating, CTDI is equal to the area of the dose profile divided by nT, the nominal beam width. In practice, CTDI is restrictively measured using a 100 mm long (3 cm^3 active volume) CT pencil ionization chamber, the dose profile being accumulated over the