A single institution study of radiation dose received from CT imaging: A comparison to Malaysian NDRL

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Abstract. Advancement of CT technology has led to an increase in CT scanning as it improves the diagnosis. However, it is important to assess health risk of patients associated with ionising radiation received from CT. This study evaluated current dose distributions at Advanced Medical and Dental Institute (AMDI), Malaysia and was used to establish Local Diagnostic Reference Level (LDRL). Dose indicators such as CT Dose Index (CTDI\textsubscript{vol} and CTDI\textsubscript{w}) and Dose-Length Product (DLP) were gathered for all routine CT examinations performed at the Imaging Unit, AMDI from January 2015 to June 2016. The first and third quartile values for each dose indicator were determined. A total of 364 CT studies were performed during that period with the highest number of cases being Thorax-Abdomen-Pelvis (TAP) study (57\% of total study). The CTDI\textsubscript{w} ranged between 2.0 mGy to 23.4 mGy per procedure. DLP values were ranged between 94 mGy.cm to 1687 mGy.cm. The local dose data was compared with the national DRL to monitor the current CT practice at AMDI and LDRL will be established from the calculated third quartile values of dose distribution. From the results, some of the local dose values exceeded the Malaysian and further evaluation is important to ensure the dose optimisation for patients.

1. Introduction

With the technology advancement in CT imaging, it has been performed more frequently as patients can benefit from a quicker procedure and more accurate diagnosis. However, critical attention must be given to assess the health risk associated with the ionising radiation received by patients during CT examination. According to the International Commission on Radiological Protection (ICRP), the radiation exposure received from the diagnostic radiology should be justified and optimized [1–2]. Therefore, in this study, the local radiation dose data for all CT examinations performed in AMDI, Malaysia were reviewed and compared with the standard value from the National Diagnostic Reference Level (NDRLs) provided by Ministry of Health (MOH) Malaysia [3]. By comparing the Local Diagnostic Reference Levels LDRLs with standard NDRLs, this will enable optimisation of current local CT practices on exposure settings and
protocol selection in AMDI. The local dose distribution can also improve by reducing the frequency of unjustified exposure and recommending corrective actions for dose reduction.

The first clinical CT scan on a patient in AMDI took place on 1st January 2015. In this centre, CT delivers large numbers of the collective effective dose received for diagnostic imaging procedures. This study also intends to establish a LDRL standard for each CT protocol performed in AMDI. The DRLs are recommended as an optimisation tool to help manage the radiation dose to patients so that the dose received commensurate with clinical purposes [4–9]. The establishment of LDRL can serve as a dose guideline that for diagnostic and therapeutic procedures. With the documentation of the local dose data, it will be useful for the verification of current radiation protection program in this centre.

2. Methodology
The dose survey was performed on patients’ data from Siemens SOMATOM AS+ CT scanner (Siemens Healthcare, Germany) at Imaging Unit, Clinical Trial Complex, AMDI, in Malaysia. The dose data for all CT protocols were collected from January 2015 until June 2016. Institutional committee review for ethical approval on clinical data study was obtained (USM/JEPeM/16040164) and there were no exclusion criteria for the selection of patients.

The exposure setting and patient information were obtained from CT consoles: tube potential (kV), effective tube current (mAs), shift per rotation ratio (pitch), slice thickness, scan range, patient’s gender, and age for all the routine examination. The displayed dose output such as CTDI$_{vol}$, and DLP were collected from CT scanner. However, the national DRLs recommended for CT are expressed in CTDI$_w$ (mGy) and DLP (mGy.cm) [3]. The weighted computed tomography dose index (CTDI$_w$) was calculated using the following formula:

$$CTDI_w = CTDI_{vol} \times pitch$$

Minimum, mean, maximum, the first and third quartile values for each CTDI$_w$, CTDI$_{vol}$ and DLP of all CT protocol were calculated respectively. The dose indicator values were then analysed and compared with the national guidelines of DRLs. The local DRLs for this centre will be established from the calculated values of the third quartile of mean of patient dose distribution for each type of examination. In accordance with the standard regulations, the LDRL should be established after a three year period of data collection or minimum of 10 cases [6–8]. All the collected dose data were then documented for annual clinical evaluation of current local practices in CT examination. If the radiation doses exceed the NDRLs, an appropriate local review should be performed and recommendation for the corrective actions to reduce radiation dose should be proposed to the Imaging Department, AMDI.

3. Results
From the dose survey done at Imaging Department, AMDI, a total of 364 CT examinations’ data were observed for. The total number of CT study and acquisition settings for different CT protocols obtained in the survey is presented in table 1. The highest number of CT procedure collected was TAP region for 57% of the total cases; while the least number was spine, cardiac, and head–neck study (1% respectively).

From table 1, it is noted that the acquisition parameters used in this survey show a wide variation, except for slice thickness selection that are typically at constant value of 0.6. The highest value for effective mAs was noted in CT TAP study with a value of 498 mAs whereas the lowest value of 17 mAs was found in the abdomen-pelvis study (Table 1).
Table 1. Range of CT acquisition parameters collected in this study.

| CT protocols  | n\textsuperscript{a} | Tube voltage (kVp) | Eff. tube current (mAs) | Pitch | Slice thickness |
|---------------|----------------------|-------------------|------------------------|-------|----------------|
| Abdomen       | 58                   | 80–140            | 33–421                 | 0.6–1.2 | 0.6            |
| Abd-Pelvis    | 10                   | 80–140            | 17–334                 | 0.6–1.4 | 0.6            |
| Brain / Head  | 34                   | 100–120           | 56–496                 | 0.55–1.2 | 0.3–0.6       |
| Cardiac       | 2                    | 120               | 22–127                 | 0.2    | 0.6            |
| Head-Neck     | 2                    | 100               | 125–276                | 0.8    | 0.6            |
| Neck          | 6                    | 80–120            | 93–330                 | 0.8–1.2 | 0.6            |
| Neck-Thorax   | 3                    | 100–120           | 85–279                 | 0.6    | 0.6            |
| NTAP\textsuperscript{b} | 13               | 100–140           | 94–333                 | 0.6    | 0.6            |
| Pelvis        | 2                    | 100–120           | 145–206                | 0.6–0.8 | 0.6            |
| Spine         | 3                    | 100–120           | 231–406                | 0.6–1.2 | 0.6            |
| TAP\textsuperscript{c} | 209             | 100–140           | 84–498                 | 0.6    | 0.6            |
| Thorax-Abd    | 7                    | 100–120           | 112–327                | 0.6–0.8 | 0.6            |
| Thorax        | 15                   | 100–140           | 101–397                | 0.6–1.3 | 0.6            |

\textsuperscript{a} number of cases.
\textsuperscript{b} Neck-Thorax-Abdomen-Pelvis region.
\textsuperscript{c} Thorax-Abdomen-Pelvis region.

Figure 1 shows the distribution of CTDI\textsubscript{w} values for various CT protocols collected which includes abdomen region (Abd), abdomen-pelvis (AP), cardiac, head, neck, neck-thorax (NT), neck-thorax-abdomen-pelvis (NTAP), spine, pelvis, thorax-abdomen-pelvis (TAP), thorax, and thorax-abdomen region (TA). The CTDI\textsubscript{w} ranged between 0.90 mGy to 98.7 mGy per procedure. The highest value of cumulative CTDI\textsubscript{w} was noted in the CT neck–thorax–abdomen–pelvis (NTAP) examinations, with a maximum value of 98.7 mGy, whereas the lowest value of 0.90 mGy was recorded for the CT cardiac study.

Figure 2 shows the distribution of collected DLP values for each CT protocol of different scanning regions. As depicted in the figure, CT head study has the highest value of cumulative DLP with a maximum value of 4401 mGy.cm, whereas the lowest DLP value of 64 mGy.cm was recorded for the CT cardiac study. The CT cardiac has lowest values of both CTDI\textsubscript{w} and DLP. A great variation of DLP distribution can be observed in CT head study (Figure 2). These variations may be due to the selection of the imaging protocols markedly in greater range of the selected mAs, and the multiple exposures for contrast enhancement study during the monitoring scanning.

Table 2 shows the comparison of local dose data (the third quartile value of the dose distribution) in this study with the standard NDRL set by MOH Malaysia. As depicted in the table, some of the local dose values in specific body regions exceeded the NDRL values such as abdomen, pelvis, thorax, and spine CT study, and thorough evaluation is required to assess higher radiation dose possibly received by patients and to propose the correction procedure strategy.
**Figure 1.** CTDI\(_w\) (mGy) distribution for each CT protocol.

**Figure 2.** Dose-length product (DLP) distribution for each CT procedure.
Table 2. Comparison of local CT dose data in AMDI with the reference values of NDRL.

| Examination types | CTDI<sub>w</sub> (mGy) | DLP (mGy.cm) |
|-------------------|------------------------|--------------|
|                   | This study<sup>a</sup> | NDRL<sup>b</sup> | % difference | This study<sup>a</sup> | NDRL<sup>b</sup> | % difference |
| Abdomen           | 12.6                   | 12.8         | 1.56         | 466         | 450         | 3.56         |
| Brain / Head      | 49.5                   | 46.8         | 5.77         | 995         | 1050        | 5.23         |
| Cardiac           | 21.0                   | 11.8         | 77.9         | 295         | 870         | 66.1         |
| Pelvis            | 29.4                   | 39.1         | 24.8         | 632         | 730         | 13.4         |
| Spine             | 21.0                   | 16.3         | 28.8         | 578         | 390         | 48.2         |
| Thorax            | 33.8                   | 21.3         | 58.7         | 642         | 420         | 52.9         |

<sup>a</sup> Local dose data in this study were set at the level of third quartile value for CTDI<sub>w</sub> and DLP.

<sup>b</sup> NDRL values are based on reference standard established by MOH Malaysia [3].

4. Discussion

The radiation dose received from CT imaging mostly depends on the CT acquisition parameters, including tube potential (kVp), tube current (mAs), and shift per rotation ratio (pitch). From our observation, a great variation of dose (CTDI<sub>w</sub> and DLP) distribution was observed in certain study protocols, which were CT NTAP and CT head study, respectively (Figure 2 and 3). These variations may be due to the acquisition parameters selection because of the higher selected mAs values, and the higher dose values may be due to multiple exposures from pre- and monitoring contrast protocols. In this study, the dose survey done can help promote the improvement in patient protection at AMDI.

The third quartile values of the collected local doses were compared with the national DRL of Malaysian regulation [3]. From table 2, some of the local dose values in specific body regions exceeded the Malaysian NDRLs for CTDI<sub>w</sub> and DLP by factors ranged from 0.03 to 0.7. As reported by previous finding, the current Malaysian DRLs are based on dose surveys taken from 2007 to 2009, which comprises of dose data obtained mainly from single slice (SSCT) scanners [11]. Theoretically, the doses received from multi-slice (MSCT) scanner were slightly higher than SSCT scanner. This is also one of the major factors that contribute to higher local dose at AMDI as compared to the NDRLs dose.

As the first step in optimisation strategies at AMDI, a local DRL will be established based on the standard regulations [3,6]. The radiation dose surveys have been suggested to be performed constantly in order to monitor CT dose trends received by our local patients. Besides, this regular review can help identify the influencing features that affect patient doses in CT and to keep all doses within acceptable ranges for optimisation of radiation protection. A local dose database should also be established as a sustainable resource for monitoring dose trends in CT examinations.

However, there were several limitations in this study. This study is limited by the small sample size within certain CT protocols that constricted the establishment of local DRLs. The comparative study on the dose data is done only for selected CT protocols that are available for comparison based on NRLs, as depicted in table 2. Thus, examination-specific DRLs for the unavailable CT protocols in the current NDRLs should be established at the institutional level for local reference to portray our current practice. The Malaysian DRLs also did not specify the detailed procedures for each reference value.
5. Conclusion

From the local dose investigation, it indicates that some of the dose values exceeded the standard requirement set by MOH. Further evaluation is critical to ensure the dose optimisation for patients and to reduce the occurrence of excessive radiation exposure. Appropriate selection of exposure parameters and scanning techniques should be selected for dose justification. A corrective strategy for dose reduction should be proposed to the department as a part of local radiation protection program such as establishment of standard CT acquisition protocols based on individual patient’s size and body-mass index (BMI).

6. References

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