The establishment of the national dose reference level (DRL) for head-CT examination in Indonesia

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Abstract. The dose reference level (DRL) is one of the tools for dose optimization in every radiological practice. However, Indonesia does not have a national DRL for CT which can be adopted nationally to date. This research was aimed to develop the national DRL for the head CT examination. There were 636 survey booklets with 20,211 patient data. All data then were classified into contrast and non-contrast parameters. Outliers data were removed from the data list by z-score. MATLAB R2017b was used to determine minimum, maximum, the first, second and third quartile values. The third quartile of data was identified as the DRL value. It was found that national DRLs in terms of CTDIvol, DLP, and effective dose were 60 mGy, 1,811 mGy-cm, and 3.8 mSv for the contrast parameter, and 61 mGy, 1,350 mGy-cm, and 2.8 mSv for the non-contrast parameter. National DRL values for males and females show the same value when stated in CTDIvol. Meanwhile, the national DRL value for males is greater than that for females when expressed in DLP and effective dose. These results are consistent with the differences in head size that is relatively larger in males than in females.

Keywords: DRL, DRL value, patient dose data, data verification, contrast head-CT, and non-contrast head-CT.

1. Introduction

Diagnostic Reference Level (DRL) is one of the means for optimizing patient dose. DRL or “investigation level” is determined by the third quartile (Q3) of the overall doses data collected from a survey [1]. DRL acts as a comparative measure to investigate whether a diagnostic service gives excessively high or low dose [2]. The DRL has been adopted by many countries across the world [3–7]. DRL is prioritized for modalities that give high doses to patients and their ability to show the patient dose value, where CT-scan has fulfilled these two criteria [8]. DRL is also prioritized for the most frequent examination in a particular region, where CT-scan has the most data from 20,211 patients across Indonesia [1].

The study of DRL was considered as a new study in Indonesia. In 2012, the first research about DRL for head CT in Indonesia was conducted by three prominent hospitals in Malang [9]. Later in
2014, BAPETEN, as Indonesia’s national body for supervision and regulation for the utilization of nuclear energy has launched an application for patient data recorder based on a web named Si-INTAN [10]. In 2018, BAPETEN also wrote a manual document for national DRL determination in Indonesia. However, the manual has not yet accommodated all the management techniques for patient dose data collected from surveys [8]. Consequently, the official verification method and the national DRL determination systematic are still recently being studied intensively by BAPETEN. For that reason, this study is conducted to determine the values of national DRL in Indonesia.

2. Methods

2.1. Patient dose data
There were 636 survey booklets with 20,211 patient data compiled by Si-INTAN from 2015 to 2018 for head-CT examination. Dose information of each patient was provided in the form of the volume-CT dose index (CTDIvol) and dose-length product (DLP) radiation dose metric. The effective dose was calculated by the ImPACT software.

2.2. Data preparation
Data preparation consisted of two stages: grouping and data coding. A total of 636 survey booklets were grouped into contrast and non-contrast. It was found that 120 and 516 survey booklets for each contrast and non-contrast. 120 survey booklets contained 3,215 patient data, while 516 survey booklets contained 19,996 patient data. The data were calculated and analyzed using MATLAB software. Detailed information about the number of patients for each patient’s gender was shown in Table 1.

2.3. Patient dose data verification
Data of patient dose were manually uploaded into Si-INTAN by the user, which meant the user has to type one by one the patient dose into the survey booklets before it was uploaded into Si-INTAN. This could increase the errors of the data recorded by Si-INTAN. Moreover, Si-INTAN has not implemented a verification system yet for the data uploaded by users. Thus, the verification method is important to obtain reliable data. Verification was carried out through two stages, namely data selection and data elimination. This verification was carried out using Microsoft Excel 2007.

2.3.1 Data selection
The data selection process was done by removing the CTDIvol and DLP values that are out of the range of 5 - 150 mGy and 5 - 6,000 mGy-cm. The range was chosen based on the minimum and maximum doses on the head-CT examination that has been previously studied [3–5,11,12]. A set of patient dose data that had passed through this stage is then referred to as acceptable data.

2.3.2 Data elimination
Data elimination was a process for handling outliers on acceptable data. One way to handle outliers is to carry out a transformation approach [13]. Outlier data was detected by the z-score. A dose data that has a z-score of more than 2.5 was considered as outlier data and then deleted from the acceptable data.

2.4. Effective dose calculation
The effective dose is the best quantity to relate cancer risk from CT examination. It was calculated by taking into account the magnitude of the organ dose and sensitivity of each exposed organ. The effective dose (E) was calculated using $E = DLP \times k$ equation, where $k$ is the conversion factor of the effective dose. This study uses $k = 0.0021$ (mSv.mGy-1.cm-1) [14].
2.5. DRL calculation
National DRL calculations were performed using the MATLAB R2017b. The output from MATLAB R2017b computation for each region was the minimum, maximum, 1st quartile (Q1), 2nd quartile (Q2), and 3rd quartile (Q3) that were then identified as the DRL value itself.

3. Results and Discussion

3.1. Information on survey contributor
Through a data recapitulation, there were 96 hospitals (between A to D class) who actively uploaded the survey booklet into the Si-INTAN system between 2015 and 2018. There were 47 types of CT modality, 85% of them were multiple-detector (MDCT) and 8.5% of them were dual-detector (DDCT). The brand of CT modality was dominated by General Electric (GE) and Siemens with each percentage for 32% and 30%, while the rest 38% of brands were Philips, Toshiba, Hitachi, and Neusoft. Around 70% of 636 survey booklets recorded have already applied dose modulation features, while the other 30% of survey booklets had not yet applied the feature.

3.2. Information of patients
Figure 1 (a) shows the distribution of age from 3,215 patients for contrast examination, while Figure 1 (b) shows the distribution of age from 16,996 patients for non-contrast examination. It shows that the ages of patients range between 1 to 93 years old for contrast examination and 0 to 99 years old for non-contrast examination.

Figure 1. The distribution of patients’ age on a national sample for (a) contrast examination and (b) non-contrast examination

Figure 2 shows the distribution of patients’ weight for (a) contrast examination and (b) non-contrast examination. It shows that the weights of patients range between 6 to 108 kg for contrast examination and 2 to 120 kg for non-contrast.

Figure 2. The distribution of patients’ weight on a national sample for (a) contrast examination and (b) non-contrast examination
Table 1 shows the number of patients before and after the verification is completed. It shows that after verification, the total patients are 2,869 and 16,076 for contrast and non-contrast examinations, respectively.

| Patient Gender | Contrast | Non-contrast |
|----------------|----------|--------------|
|                | Initial  | Final        | Initial  | Final        |
| Males          | 1,682    | 1,511        | 9,189    | 8,698        |
| Females        | 1,533    | 1,358        | 7,807    | 7,378        |
| General        | 3,215    | 2,869        | 16,996   | 16,076       |

3.3. The values of national DRL

The DRL values based on contrast and non-contrast parameter expressed in CTDIvol, DLP, and Effective dose (E) are depicted in Figure 3. Figure 3(a) shows that the DRL value for male and female patients in CTDIvol. It shows that the same DRL is achieved for male and female patients. The CTDIvol for contras examination (60 mGy) is slightly greater than for non-contras examination (61 mGy).

However, Figure 3(b) shows that the DRL value for DLP is higher for contrast examination compared to non-contrast examination. Because the E is directly calculated from DLP, hence the E for contrast CT examination is greater than for non-contras examination.

![Figure 3](image-url)
In addition to the DRL (Q3), the first quartile (Q1) and second quartile (Q2) were calculated in this study. The Q1 and Q2 values for CTDI\textsubscript{vol}, DLP and E are tabulated in Table 2.

Table 2. The Q1 and Q2 for head-CT expressed in terms of CTDI\textsubscript{vol} (mGy), DLP (mGy-cm), and effective dose [E (mSv)] respectively

| Parameters                      | Contrast | Non-contrast |
|---------------------------------|----------|--------------|
|                                 | General  | Males        | Females   | General | Males | Females |
| First Quartile (Q1)             |          |              |           |         |       |         |
| CTDI\textsubscript{vol}         | 43       | 43           | 43        | 43      | 43    | 43      |
| DLP                             | 1,034    | 1,078        | 1,021     | 813     | 876   | 810     |
| E                               | 2.2      | 2.2          | 2.1       | 1.7     | 1.8   | 1.7     |
| Second Quartile (Q2)            |          |              |           |         |       |         |
| CTDI\textsubscript{vol}         | 55       | 55           | 55        | 59      | 59    | 59      |
| DLP                             | 1,230    | 1,257        | 1,219     | 1,152   | 1,174 | 1,146   |
| E                               | 2.6      | 2.5          | 2.6       | 2.4     | 2.5   | 2.4     |

3.4. The Comparison between DRL values in Indonesia and other countries

The comparison between DRL values from this study (Indonesia) and other countries are tabulated in Table 3. The (*) sign in Table 3 indicated that the DRL value is obtained from the non-contrast examination. Based on Table 3, the DRL value in Indonesia expressed in CTDI\textsubscript{vol} is 61 mGy, which is equally the same as in Kenya and Nigeria, and is lower than in Portugal, Italy, and Japan with each margin of 14, 8, and 24 mGy, but is higher than in Luxemburg and Cameroon where the value is only 52 mGy. Nevertheless, the DRL value in Indonesia is the same as 36 countries across Europe. Based on the European Commission, the frequent DRL value recorded is 60 mGy[15].

Table 3. The comparison of national DRL value in Indonesia and other countries

| Country             | CTDI\textsubscript{vol} | DLP (mGy-cm) | Effective Dose (E) (mSv) |
|---------------------|--------------------------|--------------|--------------------------|
| Indonesia (this research) | 60/61*                  | 1.811/1,350* | 3.8/2.8*                 |
| Indonesia [8]       | 62.08                    | 1,371        | -                        |
| Kenya [4]           | 61                       | 1,612        | 3.0                      |
| Portugal [16]       | 75                       | 1,010        | -                        |
| Italy [17]          | 69                       | 1,382        | -                        |
| Japan [18]          | 85                       | 1,350        | -                        |
| Luxemburg [19]      | 52                       | 1,270        | -                        |
| Nigeria [7]         | 61                       | 1,310        | 2.75                     |
| Cameroon [6]        | 52                       | 1,151        | -                        |

However, the analysis from the DLP will give different results. The DRL value in Indonesia expressed in DLP has a lower value than in Kenya and Italy, with each margin of 215 and 21 mGy-cm, but higher than in Portugal, Japan, Luxemburg, Nigeria, and Cameroon with each margin of 351, 11, 91, 51, and 210 mGy-cm. The DRL value in Indonesia expressed in DLP is also higher than the report from the European Commission, where the value is only 1,000 mGy-cm. Therefore, the DRL value in Indonesia both expressed in CTDI\textsubscript{vol} and DLP is still acceptable since the margin is not that significant, as well as the DRL expressed in effective dose. However, the DRL value in Indonesia expressed in effective dose shows a higher value than the value recommended by Mettler et al [20].
4. Conclusions
The national DRL value for CTDIvol, DLP, and effective dose in the head CT examination have been developed by using the national dose data registry of Si-INTAN. It was found that national DRLs in terms of CTDIvol, DLP and effective dose were 60 mGy, 1,811 mGy-cm, and 3.8 mSv for the contrast parameter, and 61 mGy, 1,350 mGy-cm, and 2.8 mSv for the non-contrast parameter. These DRL values are relatively comparable to DRL values of other countries.

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