Establishment Diagnostic Reference Level for CT-Scan Procedure in Indonesia

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Abstract. Diagnostic Reference Level (DRL) is an effective tool in an effort to increase optimization. The purpose of this study is to establish Indonesian DRL (IDRL) for CT-Scan modality for adult patients. Data collection was done by collecting data from each hospital through SI-INTAN application. The minimum data that have to be reported was 20 patients per procedure for each hospital. IDRL analysis was carried out if there are at least 20 hospitals participating in the survey for certain procedures. Establishment of IDRL was based on an analysis of 75 percentiles from each hospital DRL, while the hospital DRL was based on the median of patient data. IDRL analysis for CT-Scan was based on CTDIvol and DLP quantity. In addition, an analysis of the scan length of 1-phase procedure was done. The analysis was carried out for some procedures, Head, Chest and Abdopelvis. For CTDIvol, the IDRLs were 65mGy, 14mGy and 17mGy for Head, Chest, and Abdopelvis respectively. For DLP, the IDRLs were 1400 mGy.cm, 759 mGy.cm and 1350 mGy.cm for Head, Chest, and Abdopelvis respectively. Based on scan length analysis, information was obtained that most Head procedures were carried out between 16-25 cm. While the scan length for Chest procedure was 31-50 cm and for Abdopelvis was 41-65 cm. From these results, this study can be used as profile baseline of IDRL for CT-Scan modality in Indonesia. The results indicate that optimization must be done for CT-Scan in Indonesia.

Keyword: Diagnostic Reference Level, Optimization, CT-Scan, Head, Chest, Abdopelvis

1. Introduction

CT Scan is ionizing radiation modality that is often used because it is able to provide 3D images with good spatial resolution [1-2]. However, the CT Scan also provides higher dose if compared with conventional radiography that will certainly increase the cancer risk of the patient [3-8]. In order to reduce the dose given to patients, optimization is needed to meet the principle of ALARA (as low as reasonably achievable) with good diagnostic quality [9-15]. Based on the recommendation of The International Commission on Radiological Protection (ICRP) Publication 101, the implementation of optimization must be done with cooperation between stakeholders and the regulatory body [16]. Diagnostic Reference Level (DRL) is one effective tool used to improve optimization [17-18]. A review must be carried out by the hospital’s team (medical physicists, radiologists, radiographers and radiation protection officers) to improve optimization if DRL is exceeded.

DRL was first applied in the United Kingdom (UK) in the 1980s with surveys conducted every 5 years [19]. In addition, the International Atomic Energy Agency (IAEA) also recommends the use of DRL in optimization [20]. Several studies have shown that DRL can improve optimization to decrease the dose given to patients [21-22].
At this time, Indonesia has not yet set a National DRL. In this study, the Indonesian DRL (IDRL) analysis was performed for CT Scan modality for adult patients. The purpose of this study is to establish Indonesian DRL (IDRL) for CT-Scan modality. DRL analysis of CT-Scan was prioritized because CT-Scan is the modality that often used in diagnostic procedure and provides high dose if compared with other diagnostic modalities. Data collection was done by a web-based application. The survey was conducted in the period from January 2015 to December 2018. From IDRLs analysis, optimization for medical exposure for CT-Scan Modality in Indonesia can be evaluated and compared with DRLs from other countries.

2. Method
The survey of CT scan modality was carried out using a web-based application called Si-INTAN (Patient Radiation Dose Information Systems). Through the application, the hospital should input data of a certain procedure with a minimum of 20 patients. From these data, the hospital DRL was analyzed based on the median or Q2 of the distribution of patient dose data. IDRL was analyzed based on 75 percentiles or Q3 from the distribution of hospital DRLs. IDRL for a certain procedure was analyzed if there were at least 20 hospitals participating in the survey. In CT Scan modalities, analysis of hospital DRLs and IDRLs were performed on the quantity of Computed Tomography Dose Index (CTDIvol) and Dose Length Product (DLP), because those quantities are easily measured and also determined radiation metric that related to the amount of ionizing radiation exposed to the patient in CT-Scan Modality [22-25]. In the analysis of the IDRL, an analysis of 95% Confidence Interval (95% CI) was obtained from the equation [26]

\[
95\% CI = DRL \pm 1.96 \frac{\sigma}{\sqrt{N}}
\]  

with N is the number of hospitals that contribute to the survey, and \(\sigma\) is the standard deviation obtained by the equation [27]

\[
\sigma = \sqrt{\frac{\sum_{i=1}^{N} (x_i - \bar{x})^2}{N-1}}
\]

In this study, a comparison of scan length from 1 phase for each procedure was also carried out. Determination of scan length was carried out based on the equation [19]

\[
Scan \ length \ (cm) = \frac{DLP \ (mGy)}{CTDI_{vol} \ (mGy)}
\]

To find out the quality of optimization that has been applied in Indonesia, IDRLs was compared with DRLs in several countries.

3. Results and Discussions
Based on the survey conducted from January 2015 to December 2018, there were 3 procedures that met the requirements for the number of hospital participation. The procedures analyzed in this study are shown in Table 1.

| No. | Procedures   | No. of hospitals | DRL CTDI\(_{vol}\) (mGy) | DRL DLP (mGy.cm) |
|-----|--------------|------------------|--------------------------|------------------|
| 1   | Abdopelvis   | 36               | 17                       | 1350             |
| 2   | Chest        | 21               | 14                       | 759              |
| 3   | Head         | 82               | 65                       | 1400             |

Distribution of hospital DRLs for the procedures is shown in Figure 1 for CTDI\(_{vol}\) analysis and Figure 2 for DLP analysis. On Abdopelvis procedure, the IDRLs for CTDI\(_{vol}\) and DLP were 17 mGy and 1350 mGy.cm respectively. As for the Chest procedure, the IDRLs were 14 mGy and 759 mGy.cm for CTDI\(_{vol}\)
and DLP respectively. For Head procedure, the IDRLs were 65 mGy for CTDI$_{vol}$ and 1400 mGy.cm for DLP.

![Figure 1. Hospital DRLs distribution for CTDI$_{vol}$ for some procedures: (a) Abdopelvis, (b) Chest, (c) Head](image)

![Figure 2. Hospital DRLs distribution for DLP for some procedures: (a) Abdopelvis, (b) Chest, (c) Head](image)
From the profile of the hospital DRL in Figure 1 and Figure 2, these show that there is a wide optimization gap between the hospitals participating in the survey. The gap can be seen from the hospitals that have very high hospital DRLs that exceed 2 times of IDRLs. The profiles also show that there are hospitals that have higher hospital DRL values than the IDRL on CTDI_{vol} but are lower than the IDRL on DLP and vice versa. This shows that the identification of optimization must be done specifically by each hospital to strive for a lower hospital DRL than IDRL.

The analysis of 95% confidence intervals (95% CI) of the IDRLs for each procedure is shown in Figure 3 (a) for CTDI_{vol} and Figure 3 (b) for DLP. It is important to note that the 95% CI value does not represent conditions in general in Indonesia but only represents the hospitals participating in the survey. The range of values generated from 95% CI can indicate the implementation of optimization from participating hospitals. The better and identical implementation of optimization will produce a narrower 95% CI range.

One aspect of optimization that can be evaluated in the CT Scan is the scan length performed on the patient [28]. Based on the scan length analysis carried out for 1 phase procedures, the results obtained are as shown in Figure 4. In the Abdopelvis procedure, the scans, in general, are performed in the range of 41 to 55 cm. On the Chest procedure, the scans are performed between 31 and 50 cm. While on Head procedure, the scans are performed in the range of 16 to 25 cm. The scan length can be influenced by the specific organ being examined.

The result of the IDRLs analysis were compared to DRLs from several countries. The comparison result is shown in Table 2. From this comparison, it can be seen that the IDRLs, especially for CTDI_{vol}, are quite good. However, the IDRLs based on DLP are very high, so the optimization of each procedure are necessary to be done. If the IDRLs based on DLP is compared to several countries, it is seen that the IDRL has the highest value. However, this was the first time IDRL analysis to be done in Indonesia. An improvement of optimization must be established to expect the decrease of IDRL that can be obtained for next analysis period.

The optimization can be done by some techniques. Using Automatic Exposure Control (AEC) for some procedures can decrease the dose by maintaining the tube current regardless of patients size [12]. Reconstruction technique such as iterative reconstruction can also improve the optimization that can reduce the dose [14]. The scan must be done in correct scan length and also correct pitch to reduce the dose without ignoring the diagnostic image quality.
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Figure 4. Histogram of scan length for some procedure: (a) Abdopelvis, (b) Chest, (c) Head

Table 2. Indonesian DRL compared with other countries [19, 22, 26, 27]

| National DRL      | DRL CTDI_{vol} (mGy) | DRL DLP (mGy.cm) |
|-------------------|----------------------|------------------|
|                   | Abdopelvis | Chest | Head | Abdopelvis | Chest | Head |
| Indonesian DRL 2018 | 17         | 14    | 65   | 1350        | 759   | 1400  |
| Australia (2012) [19] | 15         | 15    | 60   | 700         | 450   | 1000  |
| United Kingdom (2011) [29] | 13         | 11    | 58   | 645         | 500   | 890   |
| Japan (2015) [30] | 20         | 15    | 85   | 1000        | 550   | 1350  |
| France (2017) [22] | 13         | 10    | 46   | 650         | 350   | 850   |

4. Conclusion

DRL analysis in Indonesia was carried out for CT Scan modalities in adult patients. The analysis was carried out for Abdopelvis, Chest and Head procedure. From the results, it was found that the IDRL for CTDI_{vol} was close to the DRL from several countries. But the IDRL for DLP is very high. In addition in this study, a scan length analysis was also obtained for the three type of procedures based on a 1-phase procedure. Through these results, it was found that optimization must be done for all three types of procedures. Optimization can be done by using AEC for some procedures and iterative reconstruction. The dose can also be reduced by selecting correct pitch and scan length for each procedure.

References

[1] Choi H R et al 2018 Optik 168 pp 54-60.
[2] Serna A et al 2018 Phys. Medica. 55 pp 1-7.
[3] Alkhorayef M et al 2018 Radiat. Phys. Chem. 155 pp 65-68.
[4] Bernier M O et al 2015 Prog. Nucl. Energ. 84 pp 116-119.
[5] Berrington de Gonzalez A et al 2009 Arch. Intern. Med. 169 (22) pp 2071-2077.
[6] Karim M K A et al 2017 Radiat. Phys. Chem 137 pp 130-134
[7] Pearce M S et al 2012 The Lancet 380 (9840) pp 499-505.
[8] Smith-Bindman R et al 2009 Arch. Intern. Med. 169 (22) pp 2078-2086.
[9] Appel E et al 2018 Clin. Radiol. 73 pp. 677.e13-677.e20
[10] Edmonds K D 2009 The Radiographer 56 (3) pp 32-37.
[11] Higaki T et al 2019 Eur. J. Radiol. 111 pp 68-75.
[12] Greffier J et al 2015 Diagn. Interv. Imag. 96 pp 477-486.
[13] Ohno Y et al 2019 Eur. J. Radiol. 111 pp 93-103.
[14] Yabuuchi H et al 2018 Eur. J. Radiol. 107 pp 209-215.
[15] The International Commission on Radiological Protection 2007 ICRP Publication 101: Assessing Dose of the Representative Person for the Purpose of Radiation Protection of the Public and the Optimisation of Radiological Protection (United Kingdom: SAGE Publishing).
[16] The International Commission on Radiological Protection 2017 ICRP Publication 135: Diagnostic Reference Levels in Medical Imaging (United Kingdom: SAGE Publishing).
[17] Martin C 2015 Radiat. Prot. Dosim. 169 pp. 1-6.
[18] Hayton A et al 2013 Australas. Phys. Eng. Sci. Med 36 pp 19-26.
[19] International Atomic Energy Agency 2014 IAEA GSR Part 3: Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards (Vienna: IAEA).
[20] Lin Z X et al 2019 Eur. J. Radiol. 113 pp 140-147.
[21] Roch P et al 2018 Eur. J. Radiol. 98 pp. 68-74.
[22] Clerkin C, Brennan S, and Mullaney L M 2018 Rep. Pract. Oncol. Radiother. 23 (5) pp 407-412.
[23] Hedgire S, Ghoshhajra B, and Kalra M 2017 Phys. Medica. 41 pp 97-103.
[24] Salama D H et al 2017 Phys. Medica. 39 pp 16-24.
[25] Conover W 1980 Practical Nonparametric Statistics (New York: John Wiley and Sons).
[26] Montgomery D 2013 Design and Analysis of Experiments Eighth Edition (Arizona: John Wiley and Sons).
[27] Badawy M K, Lane H and Galea M 2019 Curr. Probl. Diagn. Radiol. 48 (4) pp 359-362.
[28] Shrimpton P et al 2014 Doses from Computed Tomography (CT) Examinations in the UK - 2011 Review (United Kingdom: Public Health England).
[29] Japan Network for Research and Information on Medical Exposure 2015 Diagnostic Reference Levels Based on Latest Surveys in Japan http://www.radher.jp/J-RIME/report/DRLhoukokusyoEng.pdf