Calculation of Size-Specific Dose Estimation (SSDE) of The Pediatric’s Head for Tube Current Modulation (TCM) CT Examinations

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Abstract.
Computed Tomography (CT) examinations in the pediatric patient are sensitive to the impact of ionizing radiation, which gives long-term risk. In addition, the actual radiation dose delivered during CT examinations has not been well-described mainly when using tube current modulation (TCM) technique. To quantify this effect, an algorithm for calculating radiation dose is needed. Therefore, this study aims to calculate and analyze the estimated effective dose of head examinations from 3D CT images, based on the equivalent water diameter ($D_w$) For the TCM technique. Four pediatric patients in the 0-6-year-old age groups were examinations using Somatom Definition Flash with variation in the number of slices. CTDI$_{vol}$ and Tube current values were obtained from the DICOM header. There are two main parts algorithm for $D_w$ calculation. First, images of CT data were converted to Hounsfield units (HU). Then, $D_w$ values based on the patients contour using the K-mean cluster and morphological gradient algorithm were calculated for every slice. The coefficient factor is obtained by American Association of Physicists in Medicine (AAPM) report 220. The values then multiplied by CTDI$_{vol}$ to acquire values of SSDE. The results showed that the relation between SSDE and tube current was strongly correlated with $R^2$ values of 0.982.

1. Introduction
High doses of radiation given to patients increase the risk of cancer in the sensitive organ. It is well known from the radiation dose [2]. To reduce the risk of excessive radiation exposure, optimization, and evaluation dose from CT is very concerning [3], especially in pediatric patients as small as possible to estimate patient dose efficiently. Besides, the actual radiation dose delivered during CT examinations has not been well-described mainly when using tube current modulation (TCM) technique. The tube current is dynamically changed after on the region along the Z-axis (longitudinal TCM) or angular in the XY axis. The dose using this technique can be reduced by 10-60% [3]. The dose received by a patient from a CT-scan process depends on the patient’s characteristics. To Estimate doses, the method Size-specific dose estimation (SSDE) is better for estimating the dose given to the patient [4]. Therefore, The aim of this
study is to calculate and analyze the estimated effective dose of head examinations from 3D CT images, based on the equivalent water diameter ($D_w$) for TCM technique.

We are trying to make an algorithm to calculate $D_w$ based on contouring automatically. In this study, we develop a process to get the $D_w$ and SSDE value more easily to analyze using the morphological gradient to segmentation the ROI from the patients image.

2. Materials and Methods

2.1. The Images of Patients

Four pediatrics patients underwent a CT head examination. The patients who underwent CT head examinations were three females and one male, patients ages between 0-6 years old. The patients were scanned by a CT scan Siemens SOMATOM Definition Flash at the Hasan Sadikin Hospital, Bandung, Indonesia. The scanning parameters for the head were: slice thickness 0.5 mm, voltage 100 kVp, tube current (Tube Current Modulation) TCM techniques, and a number of slices 36-37 slices.

2.2. The algorithm for automated $D_w$ and SSDE calculation

Figure 1 is the flow chart for the automated $D_w$ and SSDE calculation. There were four main parts. The first step is to read the 3D images from the DICOM file and convert all the CT data into Hounsfield units (HU) using equation 1. The second step is to contour the patient’s images automatically, and the third step is to automate the calculation of $D_w$ based on the automated contouring for every slice using the K-mean cluster and filter based on morphological gradient algorithm. And the final step is to calculate SSDE using equation 3.

$$HU = CTdata \times S_l + l_n$$  \hspace{1cm} (1)

$S_l$ is slope and $l_n$ is intercept we can also extract all data using the tag in file DICOM slope-intercept tag (0028,1052) dan (0028, 1053).

$D_w$ and SSDE calculations use axial images. Information that can be used is available in DICOM files such as current tube values, kVp, CTDI$_{vol}$, number of slices, slice thickness, the distance between pixels. This information is obtained from metadata files accessed using Python programming with the pydicom library. The value of $D_w$, is calculated using equation 2.

$$D_w = 2 \times \sqrt{\left(\frac{HU(x,y)}{1000} + 1\right) \times \frac{A_{ROI}}{\pi}}$$ \hspace{1cm} (2)

$$SSDE = f_D^{16} \times CTDI_{vol}^{16}$$  \hspace{1cm} (3)

$f_D^{16}$ is factor conversion for head from AAPM group task 220. Calculation SSDE value using CTDI$_{vol}$ then multiplied with $f_D^{16}$.

3. Result

3.1. Automated $D_w$ Calculation Based on Contouring Process

Figure 2(a) shows an original image of the head with precise slices. Figure 2(b) shows the gradient morphology process with the k-mean cluster filter and the thresholding process. This process aims to determine the image boundary of thresholding value was 200 to 700 HU. Figure 2(c) is the result of the process labeling, and Figure 2(d) is the result of contouring with borders or outlines of the image. The yellow line bordered by the original image is the limit of the calculation of the Region of Interest (ROI) image of the head.

Figure 3 shows the differences in the average value of $D_w$ based on the age of pediatric patients. 36-days-years-old patient age has the lowest average $D_w$ value compared to other pediatric patients.
Figure 1. Flow chart for automated contouring, SSDE calculation and extracted data from DICOM file.

3.2. Tube Current and SSDE

Figure 4 shows the tube current (mA) profile in every slice along the longitudinal axis (slice number). The tube current values were extracted from the DICOM file.

The relationships between the average tube current and SSDE is shown in Figure 5. The correlation tube current and SSDE is linear with $R^2$ values of 0.982.

The Figure 6 is shows the difference SSDE values for every patient. The average values of SSDE calculation results based on the automatic calculation of $D_w$ at every age-group of the patient have varying values. Patient age 36 day-years-old had the smallest average SSDE (30.28 mGy ± 3.97).
4. Discussion
This study was to estimate the values of SSDE in CT-scan with TCM. The CTDI\textsubscript{vol} was extracted from file DICOM or image patient, the tube current was also extracted from DICOM for every slice image of the patient, and the value of SSDE was calculated based on D\textsubscript{w} automated contouring. The calculated averaged D\textsubscript{w} and SSDE were compared to the other patient of different ages. The smallest D\textsubscript{w} and SSDE value was patient 36-years-old 11.74 cm and 30.28 mGy.

In the TCM technique, the tube current value at each slice changes at any time (moving dynamically), as shown in Figure 4. It is fluctuated based on the attenuating region in water equivalent diameter (D\textsubscript{w}). This study showed that the relation between D\textsubscript{w} and tube current
Figure 4. Longitudinal axis slice number for tube current in image of patient.

Figure 5. The relationship between tube current and SSDE.

Figure 6. The average SSDE calculation for every patient.
modulation in every patient would depend on the $D_w$ area. The parameters also have an impact on CTDI$_{vol}$ value. It depends on tube current modulation.

The relation between tube current and SSDE was quite interesting. The result has shown that SSDE in the TCM technique can be estimated tube current from DICOM. We have shown that there is a strong linear correlation between the tube current and SSDE with $R^2$ values of 0.982 for head regions.

5. Conclusion
We successfully to develop a calculator and an algorithm to obtained correlation Tube current and Dose using a size-specific dose estimation (SSDE) method for head pediatrics patients. The comparison SSDE and tube current which is obtained using the TCM technique is a strongly linear correlation.

6. References
[1] A.B. Kharbanda, E. Krause, Y. Lu, and K.Blumberg, Analysis of Radiation Dose to Pediatric Patients During Computed Tomography Examinations Journal of the Society for Academic Emergency Medicine, 2015
[2] C.Anam, F. Haryanto, R. Widita, I. Arif and G. Dougherty, Automated Calculation of Water-equivalent Diameter (D W ) Based on AAPM Task Group 220, Journal of Applied Clinical Medical Physics, Volume 17, No 4, 2016.
[3] C. Anam, F. Haryanto, R. Widita, I. Arif, G. Dougherty, D. McLean Volume computed tomography dose index (CTDI$_{vol}$) and size-specific dose estimate (SSDE) for tube current modulation (TCM) in CT scanning, International Journal of Radiation Research, Volume 16, No 3, 2018.
[4] AAPM 2011 Size Specific Dose Estimates (SSDE) in Pediatric and Adult Body CT Examinations (College Park: AAPM)
[5] C.McCollough, D.M. Bakalyar, M.Bostani, S.Brady, K.Boedeker, J.M. Boone,H. H.Chen-Mayer, O.I. Christianson, S.Leng B. Li, Michael F. McNitt-Gray, R.A. Nilsen, Mark P. Supanich, and J. Wang The Measurement, Reporting, and Management of Radiation Dose in CT, Report of AAPM Task Group 220: CT Dosimetry Diagnostic Imaging Council CT Committee 2014.
[6] Dawson P Patient dose in multislice CT: Why is it increasing and does it matter ? British Journal of Radiology, 77, S10-S13, 2004
[7] Y. Gao, B. Quinn, N. Pandit-Taskar, G.Behr, U.Mahmood, D.Long, X. George Xu, J.St. Germain, and L.T. Dauer Patient- specific organ and effective dose estimates in pediatric oncology computed tomography, ssociazione Italiana di Fisica Medica. 45, 146-155, 2018
[8] S. Namasivayam, M.K. Kalra, K.M. Pottala, S.M. Waldrop P.A. and HudginsOptimization of Z-Axis Automatic Exposure Control for Multidetector Row CT Evaluation of Neck and Comparison with Fixed Tube Current Technique for Image Quality and Radiation Dose, AJNR Am J Neuroradiol 7:222125, 2006.

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