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MODIFICATION OF 3 MSCT PARAMETERS USING ITERATIVE RECONSTRUCTION TECHNIQUES FOR RADIATION DOSE, IMAGE QUALITY, AND ANATOMICAL INFORMATION

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ABSTRACT

Cardiovascular Computed Tomography Angiography (CCTA) examination in diagnosing and evaluating congenital heart disease in pediatrics can make radiation exposure controversial and can lead to cancer risk. Development of parameter settings or modifications, namely tube voltage (kVp), pitch, and rotation time as an effort to optimize radiation dose to produce very low radiation dose. Apart from that, iterative reconstruction techniques are used as a reconstruction method to reduce noise to improve image quality. This study aimed to determine the effect of modifying 3 parameters using the iterative reconstruction technique on radiation dose, image quality, and anatomical information in pediatric CCTA examinations with clinical congenital heart disease at Harapan Kita Heart Hospital. Experimental research with a nonequivalent design. The results of this research are that the modification of 3 MSCT parameters and the iterative reconstruction technique produces a very low radiation dose which is significant at $p = 0.000$, with an average CTDIvol of 0.314 mGy, DLP 5.518 mGy.cm and can maintain different but not significant image quality, namely $p = 0.72$ in pulmonary artery SNR, $p = 0.88$ in ascending aorta SNR, $p = 0.37$ in pulmonary artery CNR and $p = 0.41$ in ascending aorta CNR so that it can provide anatomical information on contrast enhancement in the aorta and pulmonary artery area $p = 0.02$, extra cardiac analysis $p = 0.04$, contrast filling atria and ventricles $p = 0.05$, arterial and venous abnormalities $p = 0.01$, artifacts $p = 0.17$. Anatomical information is still informative in making a diagnosis. This study used a sample of 30 patients in the control group and intervention group using a purposive sampling method. Modification of 3 MSCT parameters with iterative reconstruction techniques provides an important contribution to the development of safe and informative scanning techniques for diagnosis.

Keywords: *MSCT, Cardiovascular CTA, congenital heart disease, radiation dose, image quality.*

INTRODUCTION

The progress of radio diagnostic examinations as medical support is growing rapidly along with advances in other medical sciences which are also greatly influenced by developments in technology, physics, chemistry, biology, electronics, and computers. Some of the medical supporting examinations include the use of radiation sources, one of which is using computed tomography to confirm the diagnosis (Sofiana et al., 2013). The development of this computed tomography modality is very rapid and can be seen in the increase in the number of rows in the detector array and image processing techniques produced by computer software. So this computed tomography technology has developed into multi-slice computed tomography.

Multislice computed tomography has a special role in detecting disease abnormalities to increase diagnostic accuracy, one of which is clinical congenital heart disease known by its other name, congenital heart disease (CHD). Congenital heart disease has an incidence rate of 8 per 1000 live births 6. Congenital heart disease remains the most common type of major congenital malformation affecting 0.8%-1.2% of live births worldwide 7. America is one of the countries that is experiencing an increase in the number of sufferers of congenital heart disease ranging from moderate to severe cases, namely around 6 per 1000 birth rates of full-term babies 8.

Congenital heart disease is one of the main factors causing death in pediatric patients and is currently experiencing a significant increase (Yamasaki et al., 2021). The frequent prevalence of congenital heart disease can be divided based on the heart organ that is experiencing problems, namely congenital heart disease with abnormalities in the walls of the heart between the atrium and ventricle barriers which can disrupt the heart's function in pumping blood and blood that collects in parts where it should not be, including tetralogy of Fallot. Schaffner et al. (2022), an abnormality that occurs when there is a combination of four heart diseases such as septal defects and stenosis of blood vessel valves from the heart to the pulmonary artery, as well as ventricular and atrial septum defects that occur when there is a gap or hole between the two chambers or heart atria (Ihlis et al., 2022; Karim et al., 2016).

In general, radiology provides radio diagnostic examinations for pediatric patients aged 0-15 years. Radiological examinations in pediatric patients often cause problems and uncooperative patients. A common obstacle that occurs in patient positioning is avoiding too much patient movement. This makes the examination take a long time and the results are not optimal. Therefore, it is very important to understand the child's psychology in communicating well and the arrangement of the examination room must be adapted to the child's psychological condition, namely by creating an attractive room design so that the child is not afraid or is more comfortable when being examined (De Oliveira Nunes et al., 2021; Granata et al., 2019).

It is important to be aware of the large radiation dose received from CCTA examinations by choosing the right parameter protocol to limit unnecessary radiation dose exposure by implementing new techniques to minimize radiation dose such as choosing the right parameter protocol, in this case, the tube voltage parameter has great potential to increased exposure to radiation doses (Hausleiter et al., 2006).

One method that can be used to reduce noise but can reduce radiation dose is to use image reconstruction with an iterative reconstruction method to improve image quality. Iterative reconstruction is a repeated reconstruction technique to obtain images with low blur. To continue to improve image quality with minimal radiation doses in pediatric CCTA examinations, namely the iterative reconstruction algorithm technique which can reduce noise in clinical congenital heart disease (Yamasaki et al., 2021).

Multislice computed tomography is a potential modality in evaluating the cardiovascular system because of its high spatial and temporal resolution with various post-processing techniques. Computed Tomography provides high-resolution data for cardiovascular anatomy. The post-processing techniques are multiplanar reformation (MPR), maximum intensity projection (MIP), and volume rendering (VR). Radiation exposure is one of the disadvantages of pediatric CT imaging. This can be overcome by implementing radiation dose optimization such as repeated reconstruction techniques or often called iterative reconstruction so that a significant reduction in radiation exposure does not reduce image quality (Cury et al., 2016; Dahal et al., 2020; Wang et al., 2016).

Multislice computed tomography has fast acquisition at greatly increased rotation time so that pediatric patients do not need to hold their breath for too long because it will produce images with reduced artifacts in the pediatric patient's heart rate. The use of multislice computed tomography in the cardiovascular examination can be used to diagnose cardiovascular disorders in pediatrics with clinical congenital heart disease (Beeres et al., 2015; Chaosuwannakit et al., 2021).

Clinical examination of congenital heart disease in pediatric patients requires preparation, namely that the patient is required to fast for 4-6 hours before the examination, while patients under 4 years or who are uncooperative are given oral anesthesia by administering chloral hydrate (50-100 mg/kg; maximum dose, 2000mg) or phenobarbital sodium given IV (6 mg/kg; maximum dose 200 mg). The patient's position in the cardiovascular computed tomography angiography examination is the patient's supine position. Retrospective ECG-triggered data acquisition. A scanogram was obtained from the root of the neck including the proximal aspect of the common carotid and subclavian arteries to the level of the inferior portal vein. MSCT examination with optimal dose using 100 kV, 50 mAs, scanning time 0.5 seconds, detector collimation 64 x 0.625 mm, and gantry rotation time 0.35 seconds. Repeated reconstruction (I-dose) is used between 40% and 60% (Abd El-Rahman et al., 2017).

There are quite a lot of CCTA examinations on pediatric patients and researchers know that the resulting radiation dose exposure is very large, including pediatric patients. There is no standard operational procedure for CCTA examinations in pediatrics for very optimal radiation dose results that are capable of producing good image quality with clinical congenital disease in pediatric patients at the Harapan Kita National Heart and Blood Vessel Center Hospital, Jakarta, considering that the hospital is a referral center National heart disease, the majority of whom have clinical congenital heart disease.

CCTA examination on pediatric patients with clinical congenital heart disease at Harapan Kita Heart and Blood Vessel Center Hospital, Jakarta using the Siemens brand 128 slice MSCT with standard protocol parameters, namely 100 kVp, 1.25 pitch, rotation time 0.5 s', no technique used iterative reconstruction. The iterative reconstruction technique is only performed on pediatric patients with certain clinical conditions and pediatric patients who are obese. ADMIRE is the latest workflow enhancement from Siemens that utilizes adaptive iterative reconstruction of the projection and image space, its use can reduce noise at certain mAs levels resulting in faster reconstruction and workflow.

METHOD

The methodology used in this research was quasi-experimental with a total of 30 respondents divided into an intervention group of 15 respondents and a control group of 15 respondents. Respondents included in this study were pediatric patients suffering from cardiovascular congenital heart disease, aged 0-10 years, and patients who underwent CCTA examinations at Harapan Kita Heart and Blood Vessel Hospital. The data obtained will be analyzed in 2 stages, namely the first stage is a univariate test, and the second stage is a bivariate test to compare the intervention group with the control group.

RESULTS AND DISCUSSION

Table 1 Characteristics of the research sample based on age, gender, and body weight.

Characteristics	**Control (n=15)**		**Intervention (n=15)**		***p***
	n	**%**	**n**	**%**	
Age (Mean±SD)	3.67±2.58		3.80±3.24		
0-4 years	11	73.3	10	66.7	0.334
5-9 years	4	26.7	3	20.0	
10-14 years	0	0.0	2	13.3	
Gender					
a. Male	9	60	8	53.3	1.000
b. Female	6	40	7	46,7	
B. Body (Mean±SD)	11.51±6.75		10.43±4.40		
0-10 kg	9	60	8	53.3	1.000
11-20 kg	6	40	7	46.7	

Table 4.1 shows that there are no significant differences in the sample characteristics based on age, gender, and body weight between the control group and the intervention group. The age characteristic is most common in the modified parameter protocol compared to the standard parameter protocol, with the average age of the control group being 3.67 and the intervention group being 3.80. The highest percentage aged 0 - 4 years were in the control group, the highest percentage aged 5 - 9 years were in the control group and the highest percentage aged 10-14 years were in the intervention group. The highest percentage of males was in the control group, and the highest percentage of females was in the

intervention group. The weight characteristics of the control group and intervention group were the same. The highest percentage of body weight presentations were 0 – 10 kg in the intervention group.

Table 2 Cohen's d value for SNR image quality based on Effect Size.

SNR	Group	Sample	Mean±SD	Cohen's d Effect Size	Interpretation
Arteri pulmonalis	Intervention Control	15 15	23.86±13.60 26.76±18.30	0.179876	Weak effect
Aorta ascendency	Intervention Control	15 15	35.34±15.58 34.04±10.79	0.097009	Weak effect

Pulmonary artery Cohen's d = (23.86-2676)/1612.218968 = 0.179876 Ascending aorta Cohen's d =(3534-3404)/1340.075558 = 0.097009 Modification of 3 MSCT parameters with iterative reconstruction technique showed a weak effect on the SNR image quality of the pulmonary artery and ascending aorta.

Table 3 Cohen's d value for CNR image quality based on Effect Size.

CNR	Group	Sample	Mean±SD	Cohen's d Effect Size	Interpretation
Arteri pulmonalis	Intervention Control	15 15	9.95±9.67 6.38±4.57	0.472043	Modest effect
Aorta ascendency	Intervention Control	15 15	12.34±12.29 6.38±4.64	0.641614	Moderate effect

Pulmonary artery Cohen's d =(995-638)/756.286321 = 0.472043 Ascending aorta Cohen's d =(1234-638)/928.907154 = 0.641614. Modification of 3 MSCT parameters using the iterative reconstruction technique showed a modest effect on the CNR image quality of the pulmonary artery and a moderate effect on the CNR image quality of the ascending aorta.

Table 4 Cohen's d value for contrast enhancement in the aorta area and pulmonary arteries based on Effect Size.

Anatomical information	Group	Sample	Mean±SD	Cohen's d Effect Size	Interpretation
Contrast enhancement in the aorta area and pulmonary artery	Intervention Control	15 15	3.26±0.59 2.80±0.41	0.905449	Moderate effect

Cohen's d = (326-280)/50.803543 = 0.905449. Modification of 3 MSCT parameters with an iterative reconstruction technique showed a moderate effect on the anatomical information of contrast enhancement in the aorta and pulmonary artery area.

Table 5 Cohen's d value for extracardiac analysis based on Effect Size.

Anatomical information	Group	Sample	Mean±SD	Cohen's d Effect Size	Interpretation
Extracardiac analysis	Intervention Control	15 15	3.00±0.37 2.66±0.48	0.793384	Moderate effect

Cohen's d =(300-266)/42.854405 = 0.793384. Modification of 3 MSCT parameters with an iterative reconstruction technique showed a moderate effect on extra cardiac anatomic information analysis.

Table 6 Cohen's d value for contrast filling of the atrium and ventricle (left and right) based on effect size calculations. based on Effect Size.

Anatomical information	Group	Sample	Mean±SD	Cohen's d Effect Size	Interpretation
Contrast filling atrium and ventricles (left and right)	Intervention	15	3.13±0.83	0.773537	Moderate effect
	Control	15	2,60±0.50		

Cohen's d =(313-260)/68.516421 = 0.773537. Modification of 3 MSCT parameters with the iterative reconstruction technique showed a moderate effect on the anatomical information of the contrast filling in the atrium and ventricle (left and right).

Table 7 Cohen's d values for arterial and venous abnormalities based on effect size.

Anatomical information	Group	Sample	Mean±SD	Cohen's d Effect Size	Interpretation
Abnormality Interventional arteries and veins	Intervention	15	3.13±0.83	1.029668	Strong effect
	Control	15	2,33±0.72		

Cohen's d =(313-233)/77.694916 = 1.029668. Modification of 3 parameters with the iterative reconstruction technique showed a high effect on the anatomical information of arterial and venous abnormalities.

Table 8 Cohen's d value for artifacts based on Effect Size.

Anatomical information	Group	Sample	Mean±SD	Cohen's d Effect Size	Interpretation
Artifacts	Intervention	15	1.800±0.41	26.529338	Strong effect
	Control	15	2.13±0.74		

Cohen's d = (1800-213)/59.820565 = 26.529338. Modification of 3 MSCT parameters with iterative reconstruction techniques showed a high effect on artifacts.

Table 9 Cohen's d value of radiation dose (CTDIvol(mGy), DLP mGy.cm) based on effect size.

Radiation Dose	Group	Sample	Mean±SD	Cohen's d Effect Size	Interpretation
CTDIvol	Intervention	15	0.314±0.125	**0.011947**	Weak effect
mGy	Control	15	1.370±0.000		
DLP	Intervention	15	5.518±2.747	0.956933	Strong effect
mGy.cm	Control	15	25.64±3.393		

CTDIvol Cohen's d = (0.314 – 1.37)/88.391176 = 0.011947 Modification of 3 MSCT parameters using iterative reconstruction techniques shows a high effect on CTDIvol. DLP Cohen's d = (5518-2564)/3086.94493 = 0.956933 Modification of 3 MSCT parameters with iterative reconstruction techniques shows a high effect on DLP.

Sample Characteristics

The characteristics of the selected samples were based on the criteria of age, weight, and gender. Processing of descriptive univariate test results showed that the average age, gender, and body weight in each group, both the standard protocol group and the modified group, were statistically no different (the same) (Armstrong et al., 2016).

Table 1 shows that the sample characteristics based on age are most known in the modified parameter protocol compared to the standard parameter protocol, with an average age of the control group of 3.67

and an intervention group of 3.80 at ages 0 to 4 years, indicating that the average age in each group is statistically significant. there is no difference (same) with p=0.334.

Based on gender, it is known that there are more men than women in all groups, both control and intervention groups, with a total of 15 patients, the average gender in each group is statistically no different (the same) with p=1,000.

Based on body weight, it is known that there are more patients with a body weight of 0-10 kg than patients with a body weight of 11-20 kg in all groups, both the control group and the intervention group, with a total of 15 patients with a statistically significant average weight in each group. there is no difference (same) with p=1,000.

Effect Size on optimizing radiation dose on 3 MSCT parameter modifications and iterative reconstruction techniques on image quality and anatomical information.

Table 1. shows the effect size on image quality measurements. Pulmonary artery SNR and ascending aorta SNR have a weak effect, namely with a Cohen's d value of 0.179876, and ascending aorta SNR has a weak effect with a Cohen's d value of 0.097009, but is still able to display an informative image. in establishing a diagnosis. Table 2. shows the effect size on measuring image quality. Pulmonary artery CNR has a modest effect with a Cohen's d value of 0.472043, while ascending aorta CNR has a moderate effect with an ascending aorta CNR value of 0.641614, but is still able to display informative images in making a diagnosis.

Table 3. shows the effect size on anatomical information. Contrast enhancement in the aorta and pulmonary artery area has a moderate effect with a Cohen's d value of 0.905449 but is still able to display informative images in making a diagnosis. Table 4. shows the effect size on extra cardiac anatomical information. Analysis has a moderate effect with a Cohen's d value of 0.793384 but is still able to display informative images in making a diagnosis. Table 5. shows that the effect size on the anatomical information of the contrast filling the atrium and ventricle (left and right) has a moderate effect with a Cohen's d value of 0.773537, but is still able to display an informative image in making a diagnosis.

Table 6. shows that the effect size for anatomical information on arterial and venous abnormalities has a high effect with a Cohen's d value of 1.029668, but is still able to display informative images in making a diagnosis. Table 7. shows that the effect size for artifacts has a high effect with a Cohen's d value of 26.529338, but is still able to display an informative image in making a diagnosis. Table 8. shows the effect size on CTDIvol(mGy) and DLP

In the CTDIvol calculation, Cohen's d value is infinite, because the difference in the reduction in radiation dose produced is very high (De Oliveira et al, 2021), namely with an average value of the modified parameter protocol of 0.314 mGy and an average value of the standard parameter protocol of 1.370 mGy. So the difference in radiation dose produced between the standard parameter protocol and the modified parameter protocol is relatively large.

In calculating the DLP mGy.cm for the standard parameter protocol and the modified parameter protocol, a Cohen's d value of 0.95 was obtained, with an average value of the modified parameter protocol of 5,518 mGy and an average value of the standard parameter protocol of 25.64 mGy. So the difference in radiation dose produced between the standard parameter protocol and the modified parameter protocol is relatively large.

CONCLUSION

Modification of 3 MSCT parameters using the iterative reconstruction technique has an influence on image quality, anatomical information, and CTDIvol, DLP in pediatric CCTA examinations with clinical congenital heart disease at Harapan Kita Heart and Blood Vessel Hospital. So optimizing the radiation dose by modifying 3 MSCT parameters and the iterative reconstruction technique produces a low radiation dose with an average CTDIvol of 0.314 mGy, DLP 5.518 mGy.cm and can display informative images in making a diagnosis.

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