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Submission date: 20-Jan-2020 01:56PM (UTC+0700)

Submission ID: 1243964256

File name: image_quality_on_thorax_multi_slice_computed_tomography_sca.pdf (414.49K)

Word count: 3801

Character count: 19149

International Journal of Community Medicine and Public Health
Fatmayanti H et al. Int J Community Med Public Health. 2019 Oct;6(10):4533-4537
http://www.ijcmph.com
pISSN 2394-6032 | eISSN 2394-6040

Original Research Article

DOI: http://dx.doi.org/10.18203/2394-6040.ijcmph20194525

Utilization of sinogram affirmed iterative reconstruction on 128 multi slice computed tomography scan to reduce radiation dose and improve image quality on thorax multi slice computed tomography scan: chest phantom study

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Received: 17 August 2019
Revised: 18 September 2019
Accepted: 19 September 2019

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ABSTRACT

Background: Thorax MSCT examination is a diagnostic imaging that is capable of displaying both normal and pathological lung and respiratory organs. MSCT examination also has a better level of sensitivity and specificity compared to other modalities, but the radiation exposure given is very high, so the radiation dose given to patients is high. The reduction in radiation dose is very important because of the direct exposure to sensitive tissue. One method of reducing radiation dose is by reducing the tube voltage. However, the decrease in tube voltage causes a decrease in image quality as indicated by increased noise and decreased CNR. To maintain the quality of the image at low tube voltage setting, an IR reconstruction of SAFIRE was used. The purpose of this research is to know the impact of using SAFIRE on dose radiation and image quality of thorax MSCT.
Methods: This study was an experimental study with a quasi-experimental study design. The object used was the N-1 Lungman chest phantom in which an artificial tumor was attached. Radiation dose assessment used CTDI value, while image quality assessment used noise and CNR. Data processing was conducted using linear regression test.
Results: There was an effect of tube voltage setting and SAFIRE setting on radiation dose and image quality.
Conclusions: Tube voltage ssetting and SAFIRE setting had an effect on radiation dose and image quality. Tube voltage setting and SAFIRE strength level setting that were able to provide optimal radiation dose and image quality were tube voltage of 80 kVp and SAFIRE strength levels 3 and 4 (S3 and S4).

Keywords: Thorax multi slice computed tomography, Sinogram affirmed iterative reconstruction, Radiation dose, Image quality

INTRODUCTION

Nowadays, medical equipment has experienced very rapid progress followed by technological developments that present one of the diagnostic imaging modalities called multi slice computed tomography (MSCT scan).[1] MSCT scan is capable of producing digital tomographic images, has good speed and volume coverage, provides better image quality especially at spatial resolution and temporal resolution, and has a faster scan time compared to other imaging modalities.[2]

One of the MSCT scan tests is the 'thorax MSCT' which is capable of imaging the lungs and respiratory tract organs as well as being able to display both normal and pathological lung parenchyma.[3] Thorax MSCT examination has a better level of sensitivity and specificity, but high radiation exposure causes higher cumulative effective radiation dose to patients compared to other examination.[4] High radiation exposure is detrimental to cancer patients undergoing follow-up and increases the level of concern for the harmful effects of radiation doses received by patients and other health professionals.[2,4] For this reason, it is necessary to reduce the radiation dose.

The reduction in radiation dose on thorax MSCT is very important because there is direct exposure to some radiation-sensitive tissues such as thyroid, mammary, and lungs. One method of reducing radiation dose is by decrease the tube voltage (kVp).[2–6] The tube voltage determines the photon energy and electron intensity used to determine the level of tissue attenuation.[7] Photon energy and electron intensity will affect the radiation dose given to the patient and affect the quality of the image.[8]

The decrease in image quality due to the decrease in tube voltage is characterized by the appearance of artifacts, increased noise, and decreased spatial resolution.[5] The most often seen image quality on the thorax MSCT is the noise level. Substantially, high noise will not affect diagnostic interpretation because the contrast of lung parenchyma is higher compared to other soft tissues, but in some tissues that have low contrast such as lymph nodes, blood vessels, and bones will be affected by diagnostic interpretation.[2] To improve the image quality on thorax MSCT examination, especially to reduce noise with low doses, it can be done using iterative reconstruction (IR) technique.

IR technique is an algorithm reconstruction which aims to reduce noise and maintain sharpness. One of the IR techniques is sinogram affirmed iterative reconstruction (SAFIRE). SAFIRE is a reconstruction algorithm that works on raw data and image data space with the main objective to reduce noise and maintain image sharpness.[8] SAFIRE has five strength level settings that are able to increase the contrast to noise ratio (CNR), adjust the level of noise reduction, and affect the texture of the lesion.[5,9]

The purpose of this research is to know the impact of using SAFIRE on dose radiation and image quality of thorax MSCT.

METHODS

This was an experimental study with quasi experiment study design. This study was carried out using a N-1 Lungman chest phantom in which a 12 mm artificial tumor had been installed with different HU values (-800 HU, -630 HU, and +100 HU). This research was conducted at Tugurejo Hospital Semarang in March-July 2019.

In this study the scanning of N-1 Lungman Chest Phantom was performed in accordance with the Thorax MSCT examination protocol, namely the scanning area from the lung apex to the liver, using tube voltage settings of 80 kVp, and 130 kVp, using a 70 mAs tube current, slice thickness of 8 mm, and pitch of 0.95. N-1 Lungman Chest Phantom position was head first. Then reconstruction with filtered back projection (FBP) and SAFIRE (strength levels 1-5 or S1-S5) were performed.

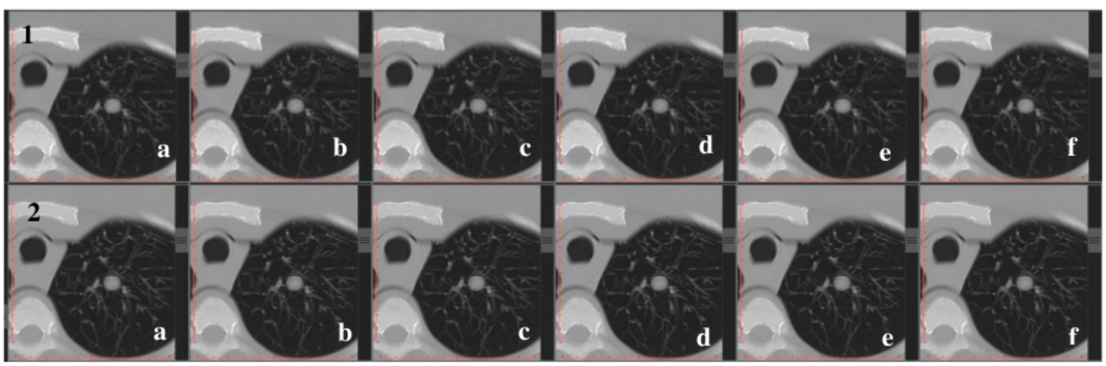

Figure 1: Study results on the thorax MSCT images with tube voltage settings of 80 kVp (1) and 130 kVp (2); and reconstruction settings of a) without SAFIRE (FBP); b) SAFIRE 1 (S1); c) SAFIRE 2 (S2); d) SAFIRE 3 (S3); e) SAFIRE 4 (S4); and f) SAFIRE 5 (S5).

Further, the radiation dose record was conducted by recording the CTDI value on the monitor screen and image quality calculation was conducted by measuring the noise and CNR values. Noise values were obtained by making ROI of ±1 mm in several organs, namely 3 artificial tumors with HU values (-800 HU, -630 HU, and +100 HU), lungs, heart, aorta, liver, aortic corpus, and foramen vertebrae. Then the standard deviation (SD) values were recorded. CNR values were obtained by making ROI in several organs, namely 3 artificial tumors with HU values (-800 HU, -630 HU, and +100 HU), lungs, heart, aorta, liver, aortic corpus, and foramen vertebrae. Then the mean and standard deviation (SD) values were recorded. After that, the calculation was conducted using the following formula:

$$CNR = \frac{A - B}{SD_B}$$

Where, A=mean value of the object, B=mean value of the background (lungs), SD_B=standard deviation value of the background (lungs).

Data analysis was conducted using statistical test of linear regression test to determine the effect of tube voltage and the use of SAFIRE on radiation dose and Thorax MSCT image quality (Figure 1).

RESULTS

Thorax MSCT examination was carried out with tube voltage variations of 80 kVp, 110 kVp and 130 kVp. Radiation dose was obtained at 80 kVp is 2.11 mGy and 130 kVp is 5.42 mGy.

The significance value of the linear regression test on the effect of tube voltage setting and the SAFIRE strength level variables on noise was 0.000<p value (0.05) which meant that there was a significant effect of tube voltage setting and SAFIRE strength level on Thorax MSCT noise (Table 1). There was a linear equation that had a negative gradient value (Figure 2), which meant that the higher the SAFIRE strength level setting used, the lower the noise produced.

The significance value of the linear regression test on the effect of tube voltage setting and the SAFIRE strength level variables on CNR was 0.000<p value (0.05) which meant that there was a significant effect of tube voltage setting and SAFIRE strength level on Thorax MSCT CNR (Table 1). There was a linear equation that had a positive gradient value (Figure 3), which meant that the higher the SAFIRE strength level setting used, the higher the CNR produced.

Table 1: Regression test results.

Variable	Variation	Anova[b] test and p value
Effect of tube voltage and SAFIRE on noise	Tube voltage of 80 kVp	Sig. 0.000, p≤0.05
	Tube voltage of 130 kVp	
Effect of tube voltage and SAFIRE on CNR	Tube voltage of 80 kVp	Sig. 0.000, p≤0.05
	Tube voltage of 130 kVp	

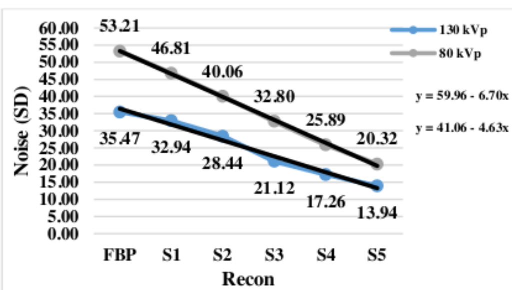

Figure 2: Effect of SAFIRE settings on thorax MSCT noise.

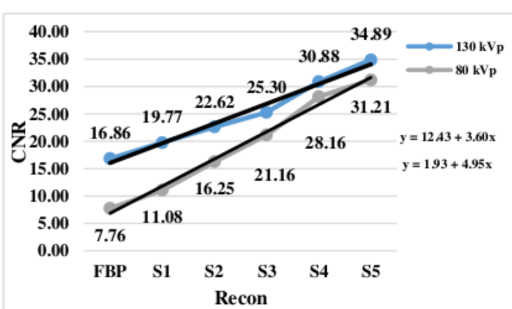

Figure 3: Effect of SAFIRE settings on thorax MSCT CNR.

DISCUSSION

Tube voltage setting on Thorax MSCT examination could reduce radiation dose, but the quality of the resulting image also decreased. The decrease in tube voltage causes the photon X-ray energy to penetrate the organ to decrease, so the radiation dose given to the patient will also decrease. The radiation dose is mathematically proportional to the square of the tube voltage (kVp^2). Thus, the selection of a high tube voltage will produce a high radiation dose. In this study a reduction in radiation dose of 61% was obtained. In addition, as much as 98% of the radiation dose on Thorax MSCT wass affected by a decrease in the tube voltage.

The study results are in accordance with previous literature, which stated that the tube voltage would determine the energy and intensity of X-ray photons that were directly related to the radiation dose. Tube voltage was directly proportional to the radiation dose, i.e., exponentially the radiation dose changes due to changes in the tube voltage between 2.5-3.1 times. Thus, the higher the tube voltage, the higher the radiation dose[7]. The radiation dose was influenced by several factors, one of which is the setting of the tube voltage (kVp). The reduction in the tube voltage from 120 kVp to 110 kVp could reduce the radiation dose by 30% and the reduction in the tube voltage of 140 to 120 kVp could reduce the radiation dose by 35%. This was due to radiation dose was linear with the tube voltage. Thus, the reduction in the tube voltage was very effective in reducing the radiation dose[2,10].

The decrease in image quality due to the decrease in tube voltage is indicated by increased noise and decreased CNR. Noise is influenced by variations in the attenuation coefficient of each organ and the number of X-ray photons captured by the detector. Low tube voltage setting results in X-ray photons attenuation or absorption by the object, so that fewer X-ray photons are captured by the detector. Meanwhile, high tube voltage setting results in more X-ray photons that penetrate the organ and are captured by the detector. This difference is indicated by the standard deviation (SD) value of the HU value. The higher the tube voltage setting, the lower the SD value and the noise obtained. CNR is the smallest difference from organs with the background. CNR is influenced by photon X-ray energy while penetrating organs. High photon energy causes high CNR. This is due to the noise obtained is low. This increase in CNR will increase the obvious difference between objects with surrounding background or surrounding organs. The difference in CNR is indicated by differences in organ density, and organ density is obtained from the attenuation coefficient difference that affects the noise level. The higher the noise level, the lower the CNR value. Conversely, the lower the noise level, the higher the CNR value.

To obtain the optimal radiation dose and Thorax MSCT image quality, some modifications need to be done. Decreasing the radiation dose was done by decreasing the tube voltage. However, the quality of the image obtained decreased, so the reconstruction was carried out using IR, SAFIRE. SAFIRE is able to maintain good image quality even though the resulting radiation dose is low. The result of this study indicated that the 80 kVp tube voltage setting was able to provide the lowest radiation dose of 2.11 mGy.

Noise reduction was due to the use of SAFIRE since SAFIRE reconstructed raw data and image space data. Data correction occurs in the raw data to eliminate artifacts. Whereas in image space data there is a multilevel sum of several data projections so that the noise obtained is lower. The results of reconstructions in the raw data and image space data are then compared until a minimum difference is obtained. This process is repeated in accordance with the selection of SAFIRE strength levels. Repetition of this process is called iteration (iterative). The results obtained are images with low noise and sharpness. Setting a low SAFIRE strength level will result in less iteration, so the resulting image will appear more noiser. Whereas in a high SAFIRE strength level setting, iteration will occur more frequently, so that the image results obtained will appear smoother. The results of this study indicated a reduction of noise by 62% using SAFIRE. As much as 72% of noise reduction was influenced by setting the SAFIRE strength level.

The results of this study are in accordance with previous literature which stated that the use of SAFIRE was able to reduce noise and maintained the sharpness of images.[11,12] In images with low exposure factors, the noise would increase. After reconstruction with SAFIRE, the image obtained was smoother.[1] The level of noise reduction is adjusted to the SAFIRE strength level setting, wherein increasing SAFIRE strength level will cause noise to decrease. In previous studies it was mentioned that the use of SAFIRE was able to reduce noise by 50-60% compared to using FBP.[6,7]

The increase in CNR is due to a decrease in noise which is the implication of the use of SAFIRE reconstruction. Setting the higher SAFIRE strength level may result in decreased noise and increased CNR. So indirectly the use of SAFIRE reconstruction will increase CNR based on the level of setting of the SAFIRE strength level used. The higher the SAFIRE strength level setting used, the higher the CNR obtained. The results showed an increase in CNR of 75% by using SAFIRE. As much as 57% increase in CNR was influenced by the setting of SAFIRE strength level.

The results of this study are consistent with previous literature, wherein the use of IR could increase CNR and affect the structure of the lesion.[5,9,12,13] In other literature it was also mentioned that in addition to reducing noise, the use of SAFIRE reconstruction could also increase CNR in accordance with the increase in the SAFIRE strength level used.[16]

Figures 2 and 3 show that 80 kVp setting with SAFIRE strength level 3 had CNR and noise values that were almost the same as the 130 kVp setting with FBP (without SAFIRE).

This is consistent with the previous literature, wherein SAFIRE was able to reduce the dose by about 65% and was able to reduce noise by 31-59% and the CNR remained good.[14] SAFIRE 2 and 3 (S2 and S3) strength levels were able to provide optimal sharpness in the lungs parenchyma and lesions.[15] SAFIRE strength level 3 (S3) was able to influence the visualization of the bronchial wall and abnormalities due to decreased attenuation.[16,17] The reduction of 120 kV tube voltage with FBP to the use of 100kV tube voltage with SAFIRE strength level 3 (S3) was able to provide optimal radiation dose and image quality. On low-dose Thorax CT, the use of SAFIRE strength level 3 (S3) provided optimal image quality. Using SAFIRE strength levels above 4 (above S4) would reduce image quality. The use of SAFIRE strength levels 1-3 (S1 and S3) was able to suppress noise more optimally. Setting the SAFIRE strength levels 2-4 (S2-S4) of on Thorax MSCT could reduce noise and improve visualization of pulmonary fissures and maintain the smallest anatomic structure of the lungs.[8,11,18–20]

Thus, it can be concluded that tube voltage setting and SAFIRE strength level could influence the radiation dose and image quality of Thorax MSCT. Tube voltage setting and SAFIRE strength level that was able to provide the most optimal radiation dose and image quality were 80 kVp and SAFIRE 3 and 4 (S3 and S4), respectively.

ACKNOWLEDGEMENTS

The authors realize that this study would have been not completed well without the assistance of co-authors and Mr. Gatot Murti Wibowo, S.Pd, M.Sc., as well as other parties. All authors have read and approved this final report.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee

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Cite this article as: Fatmayanti H, Adi K, Kartikasari Y. Utilization of sinogram affirmed iterative reconstruction on 128 multi slice computed tomography scan to reduce radiation dose and improve image quality on thorax multi slice computed tomography scan: chest phantom study. Int J Community Med Public Health 2019;6:4533-7.

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