Effect of pitch on CT image quality based on SNR evaluation using in house phantom

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Abstract. The purpose of this study was aimed to evaluate the symmetrical effect of pitch factor to SNR (Signal to Noise Ratio) in thorax phantom CT images. Thorax CT phantom was designed to contain cork and cylindrical objects with several sizes located symmetrically respect to Y-axis. Phantom size is 20 cm diameter, 22 cm length, and the objects simulated vessels filled with contrast medium (diameter A: 2mm, B: 1.7 mm, C: 1 mm, respectively). The distance between two objects: A: 6 cm, B: 8 cm, and C: 12 cm. Image acquisitions were performed:130 kVp, tube rotation 0.6s, 70 mAs, and pitch values were 0.5, 0.8, 1.0, 1.5, 1.8 and 2.0. CT images represented by 9 axial images with a slice thickness of 5 mm. The difference of SNRs (Δ): a value of ΔA, in general high at initial slice and fall significantly up to the third slice and then followed by a nearly constant value. ΔB at initial slice trend decreased with increasing slice images. ΔC at all pitch initially shown zero value and increase to maximum up to second slice (not more than 20 units) and tend to constant after at sixth slice. Effect of all pitch values on symmetrical object images was influenced by the distance between two corresponding objects and slice order. Generally at the initial slice, the SNR difference between two corresponding objects (Δ) relatively high compared with the following order slice. Therefore, in clinical practice, it is recommended to give additional FOV at least 1.5 cm at the initial slice interest.

1. Introduction

In the spiral CT technique, the term pitch is known, which is the distance (speed) of the table for one x-ray rotation in gantry (l) compared to the number and width of the detector (nT). Pitch changes will affect the spatial resolution of the patient's image and dose received. A large pitch will reduce resolution because the gap between slices is also wider, which affects the data interpolation process for image reconstruction. This is in contrast to the dose received by the patient, with a large pitch the scanning area on the z-axis will be more tenuous, so the radiation dose received by the patient decreases with a shorter scanning time. Table movements along the z-axis during the scanning process will cause motion artifacts that can reduce spatial resolution [1]. The pitch was illustrated as a pitch slice. Increasing the pitch parameter will increase the pitch slice, increase the coverage of anatomic volume per tube rotation, increase the table index speed, but decrease the dose and resolution. Pitch is formed due to the movement of the table/patient along the rotation of the gantry that crosses the anatomy of the patient in a helical configuration so that a pitch slice is formed. When the pitch slice is
perpendicular to the z-axis the maximum image resolution is obtained, so no interpolation is needed. In the axial method, data taken from each slice is axial cut data along the z-axis. Data interpolation is needed in the helical method because scanning geometry along the z-axis gives different data information [3].

![Image](image.png)

**Figure 1.** (a) In house thoracic phantom CT (b) Location of cylindrical objects

This study aims to evaluate the effect of pitch on objects located symmetrically respect to x and y axis in the thoracic phantom CT. The effect of pitch is evaluated by calculating SNR on each cylindrical objects with the same ROI on object compared to the background. The difference value of SNRs of every slice used to evaluate effect of changing pitch.

2. Materials and methods

The study was performed by using in-house thorax CT phantom and CT Siemens Somatom Emotion 16 slice were operated in Department of Radiology, Regional General Hospital of Cibinong, Bogor, Indonesia. Thorax CT phantom was made and designed based on image data CT measurement of 100 men patients. Phantom size is 20 cm diameter, 22 cm length, contain cork and cylindrical objects. The objects simulated vessels filled with contrast medium with several sizes located symmetrically respect to Y axis. Diameters of object A: 2 mm, B: 1.7 mm and C: 1 mm respectively. Distance between two objects A: 6 cm, B: 8 cm and C: 12 cm. Scanning was performed by CT thorax protocol, using 130 kVp and 70 mAs, tube rotation 0.6s and pitch values 0.5, 0.8, 1.0, 1.5, 1.8 and 2.0. CT images represented by 9 axial images with slice thickness of 5 mm.

2.1. Thorax CT phantom

The scanning was performed on CT thorax examination. Thorax was simulated by stacks of cork in 2 cm PMMA layers. The main part of CT thorax phantom was made of cork material with a density of 0.28 gr/cm³ similar to lung density (CIRS phantom 0.21 gr/cm³), size diameter 16 cm and thickness 10 mm. Soft tissue was simulated by PMMA material with a density of 1.23 gr/cm³ and thickness 2 cm around the cork.

The thorax CT phantom aims for evaluated effect of pitch on CT image quality based on SNR evaluation. The in-house phantom consist of 4 modules. The first module for evaluating image quality with SNR evaluation on cylindrical objects, second module for SNR evaluation on hole objects, third module for evaluating calcified lung on bone objects with several size of mesh. And the last was module Modulation Transfer Function (MTF) module, consists of a Cu wire lengh 40 mm with a diameter 0.3 mm, where placed on centre in-house phantom perpendicular Y axis.

Emphasis of this paper is the first module of in-house CT thorax phantom, which contain of cylindrical objects filled with contrast medium to evaluated SNR. Cylindrical objects with several size and diameters located respect to x and y axis as show in Table 1.
Table 1. Diameter and position of cylindrical objects respect to x and y axis

| Number of Objects | Outer Diameter (mm) | X-axis | Y-axis |
|-------------------|---------------------|--------|--------|
|                   |                     | Right  | Left   | Right | Left |
|                   |                     | (cm)   | (cm)   | (cm)  | (cm) |
| T (Teflon)        | 2.5 ± 0.001         | 1.5 ± 0.05 | 1.5 ± 0.05 | 1.5 ± 0.05 | 1.5 ± 0.05 |
| A                 | 2 ± 0.001           | 3 ± 0.05 | 3 ± 0.05 | 5.5 ± 0.05 | 5.5 ± 0.05 |
| B                 | 1.7 ± 0.001         | 4 ± 0.05 | 4 ± 0.05 | 4 ± 0.05 | 4 ± 0.05 |
| C1                | 1 ± 0.001           | 6 ± 0.05 | 6 ± 0.05 | 1 ± 0.05 | 1 ± 0.05 |
| C2                | 1 ± 0.001           | 3 ± 0.05 | 3 ± 0.05 | 1 ± 0.05 | 1 ± 0.05 |
| C3                | 1 ± 0.001           | 6 ± 0.05 | 6 ± 0.05 | 1 ± 0.05 | 1 ± 0.05 |
| C4                | 1 ± 0.001           | 3 ± 0.05 | 3 ± 0.05 | 1 ± 0.05 | 1 ± 0.05 |
| D                 | 1.7 ± 0.001         | 4 ± 0.05 | 4 ± 0.05 | 4 ± 0.05 | 4 ± 0.05 |
| E                 | 2 ± 0.001           | 3 ± 0.05 | 3 ± 0.05 | 5.5 ± 0.05 | 5.5 ± 0.05 |

2.2. Image quality evaluation

Scanning was performed by 130 kV and 70 mAs. The images of CT were recorded with DICOM format and will be processed using Image-J software to get pixel value of cylindrical objects that will be used to calculate SNR.

The value of SNR taken from circular region of interest (ROI) on the same size at every cylindrical objects. The SNR value will be calculated based on equation (1), as ratio between the average pixel value and standard deviation of circular regions of interest (ROI). $N_l$ was the pixel value of background and $N_{oi}$ was the pixel value of cylindrical objects, with STD was standard deviation of ROI. The difference between SNRs (Δ SNR) calculated based on equation (2) used to evaluate effect of the pitch to CT image quality.

$$\text{SNR} = \frac{|N_l - N_{oi}|}{\sqrt{\left(\frac{\text{STD}_{oi}}{2}\right)^2 + \left(\frac{\text{STD}_l}{2}\right)^2}}$$

$$\Delta \text{SNR} = |\text{SNR}_i - \text{SNR}_f|$$

This study was done at least three repetitions for image quality measurement, with SNR and Δ SNR being calculated as means from all repetitions at every slice image.

3. Results

Generally, images scanning at all pitch variations demonstrated that no visual difference results, but the calculation of SNR values shows different results. One of the results axial image phantom at pitch 1.5 for all slices is shown in Figure 2.

The difference of SNRs (Δ) value of ΔA, in general high at initial slice and fall significantly up to third slice and then followed by nearly constant value. ΔB at initial slice trend decreased with
increasing slice images. $\Delta C$ at all pitch initially shown zero value and increase to maximum up to second slice (not more than 20 units) and tend to constant after at sixth slice as shown in Figure 3.

![Axial CT image at pitch 1.5](image)

**Figure 2.** Axial CT image at pitch 1.5
4. Discussion

This study was aimed to evaluate effect of pitch on CT image quality. SNR value was calculate with at least three repetitions at every pitch and slices. Δ SNR as an image quality parameters. The results of scanning obtained 9 slices. Variations in SNR values on the left and right side of Y axis were strongly influenced during the process of ROI on cylindrical images. A large difference in background deviation also greatly affects the error value of Δ SNR in each slice. Based on measurement data with the calculation method Δ SNR can be seen the difference between the SNR of the right and left sides of the cylindrical image will change according to the change in pitch.

Point A is 3 cm from Y axis and 6 cm between two objects of A. Δ SNR A in general high at initial slice and fall significantly up to third slice, with the highest at 120 units, and nearly constantly until last slice. A signal received different due to peripheral position of cylindrical objects of the phantom. At initial scanning, the energy received by the detector is less, so there is not enough signal for image process reconstruction. At Figure 2 shown at initial slice, point A on left side has not been visualised compared right side. It causes difference signal between two cylindrical objects of A so it’s Δ SNR A increased.

Point B is 4 cm from Y axis and 8 cm between two objects of B, closer to the centre of X axis than point A. Therefore at initial slice Δ SNR B less than Δ SNR A. The signal received at the point B has different intensity due to the inadequate energy received by the detector at initial scanning. Δ SNR B at initial slice trend decreased with increasing slice images.

Whereas at point C, the initial slice is not visible, seen in the second slice (maximum 20 units) and tent to constant after sixth slice. Point C near by X-axis (6 cm from Y-axis and 12 cm between two objects C) shows less different in terms of its Δ SNR. At Figure 2 cylindrical objects of C shown at the second slice and the Δ SNR C tent to constant due to enough of energy from the entire reconstruction process.

5. Conclusion

Effect of all pitch values on symmetrical object images were influenced by distance between two corresponding objects and slice order. Generally at initial slice, the SNR difference between two corresponding objects (Δ) relatively high compared with the following order slice. Therefore, in clinical practice it is recommended to give additional FOV at least 1.5 cm at initial slice interest.

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