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COMPARISON OF IMAGE QUALITY AND RADIATION DOSE BETWEEN ANGULAR AUTOMATIC TUBE CURRENT MODULATION AND FIXED TUBE CURRENT CT SCANNING OF THORAX: PHANTOM STUDY

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ABSTRACT

Since the introduction of the CT scan, it contributes high percentage of the accumulated dose in diagnostic imaging field. The number of scan increase every year parallel to the advancement in CT scan. This trend worried the medical practitioner since the dose delivered to the patient in CT scan procedure is consider as high as compared to other imaging modalities. The aim in this experimental study is to reduce the dose by implementing an automatic tube current modulation system while attain the minimum requirement of image quality. The attempt to replace the current protocol need to be good evidence and objectively superior. The reduction in dose will benefit the patient and reduce the stochastic effect. Phantom PBH-50 has been scanned using automatic the current modulation technique and manual selection of fixed tube current of 160 mA, 200 mA, 240 mA and 280 mA. The images have been evaluated by using region of interest (ROI) analysis. The result shows that there was no significant difference in image quality for both techniques. Images acquired with automatic tube current modulation technique has a higher noise compared with the images acquired with fixed tube current. The exposure reduction around 17% till 52% can be achieved if the automatic tube current modulation technique is applied in each scanning.

Keywords: *Automatic tube current modulation, CT image quality, CT radiation dose.*

I. INTRODUCTION

CT scan is a medical equipment widely been used as a method of investigation in radiological department. By the advancement of technology, CT scan machine can produce an image in single slice with near to isotropic pixel. With the faster scan and wider coverage CT scan become more important and vital in diagnostic investigation. Faster scan allow covering the area of interest in short tie with high resolution image. The only weakness in this advancement of technology is the dose produce by CT scan machine is higher compared to the old version. It is kind of nature by gaining something we might lose. In this case, dose delivered to subjects or patients are concerned.

To reduce the radiation dose to the patient while maintaining the image quality, there are several methods can be done such as reducing the kVp, mAs or by practicing Automatic Tube Current Modulation (ATCM). With the advance technology in CT, there are other ways that can be implemented to reduce the radiation by using the advanced algorithm (iterative reconstruction), efficient detector material (short afterglow), dual source and many more. All the methods mentioned before been proposed to ensure the radiation delivered to the patient is minimal as possible. The impact will benefit the patients who are going to be scanned repeatedly to look for the progress of the diseases. The most important is the dose reduction will benefit the young children where the cell in the body is still actively dividing. As we concern, the dividing cell is the most prone cell to be affected from radiation exposure. If reducing dose to the young children is possible without jeopardizing the image quality, the protocol should be as a standard to comply the ALARA concept. This study aimed to compare between the quality of resulted images and radiation exposure associated with 128-slices CT examinations of thorax performed with the use of ATCM.

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II. METHOD & MATERIAL

This is an experimental study with the use of human thorax phantom fitted with the air and vascular lung markings which are considered as equivalent to human body Hounsfield Unit (HU) in CT examination. The soft tissue was made from urethane-based resin materials while the bony structure was constructed from epoxy-resin-based materials. Table 1 shows the details of phantom composition.

Table 1. Details of phantom composition

Material	Density g/cm3	Effective Atomic Number	Electron Density x10~23e/g	Elemental Composition (wt%)			
				H	C	N	O
Water	1.000	7.417	3.343	11.19			88.81
SZ-50	1.061	6.14	3.258	8.41	72.25	4.61	14.73

	Soft tissue	Liver	Kidneys
Hounsfield number (Approximation)	-7	70	30
Density g/cm3	1.061	1.089	1.075

Experiment

The PBH-50 thorax phantom was scanned with Somatom Definition AS+ 128 slices of Siemens with the exposure factor of 120 kVp. ATCM technique was activated for the first scan with the standard protocol of routine thorax examination as shown in Table 2.

Table 2. CT parameters of routine thorax examination

Pitch	1.2
Detector configuration	128 X 0.6 mm
Kernel	Medium – soft convolution kernel (B30f) and mediastinum window
Tube rotation time	0.5 s
Scan range	Apex of lung to costophrenic angle
Nominal slice thickness	1 mm
FOV	Apex of lung to costophrenic angle
Window width	350
Window level	50

The phantom was placed on anterposterior (AP) position on the table. The laser reference centered at the mid sagittal plane (MSP). As ATCM is activated, quality reference mAs should be set for a standard protocol since the CT machine will automatically adjusted the tube current relative to the reference mAs value. In this study, reference value of 120mAs had been recommended by the manufacturer for routine thorax examination. The scans were repeated with manual selection of fixed tube current of 160 mA, 200 mA, 240 mA and 280 mA while other parameters were kept constant. The data were transferred to the external data storage (CD ROM) before the image quality evaluation and measurement of radiation exposure take place and being extracted into SPSS for statistical data analysis. The positioning of PBH-50 thorax phantom was shown in Figure 1 and the scanning area was shown in Figure 2.

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Figure 1. Positioning of PBH-50 thorax phantom

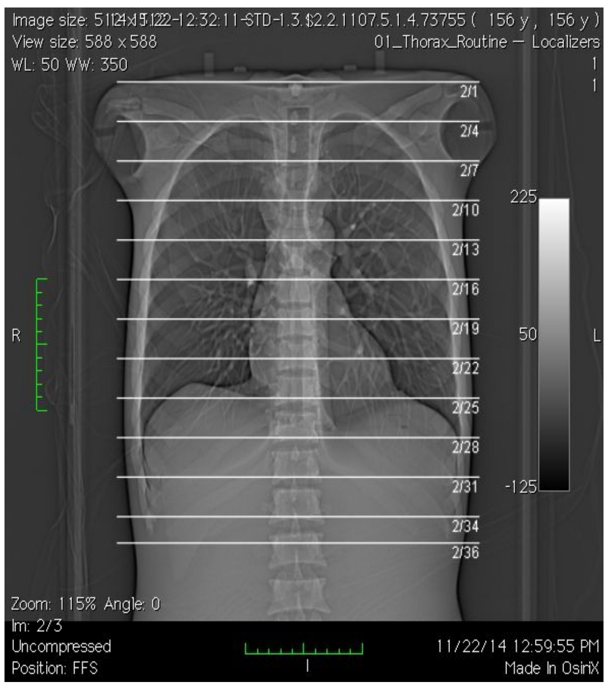

Figure 2. Scanogram of PBH-50 thorax phantom

Measurement of CT radiation exposure

CT Dose Index ($CTDI_{vol}$) and Dose Length Product (DLP) produced during the scanning were recorded into the designated table. The measurement of radiation exposure was automatically generated by the CT scanner software after the end of the examination which also includes the effective mAs or tube-current-time product values. The summary of thorax scanning protocol is shown in Figure 3.

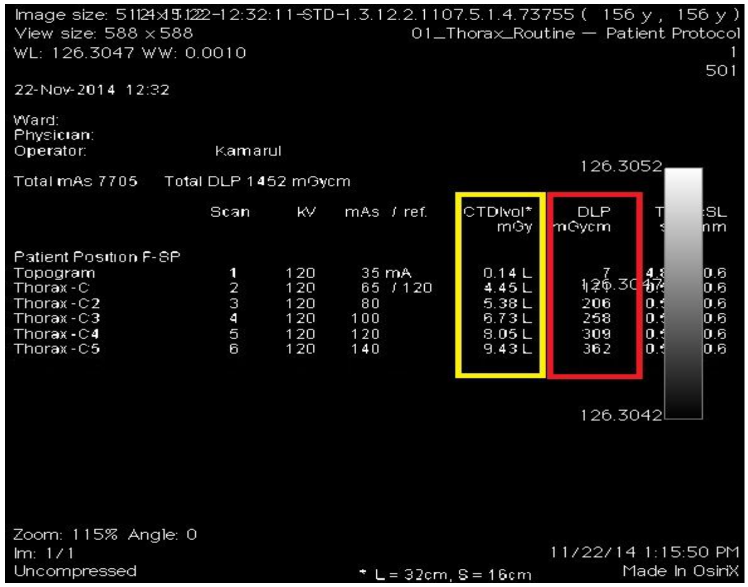

Figure 3. Summary of thorax scanning protocol

Evaluation of CT image quality

Resultant image quality was evaluated by measuring the standard deviation (SD) of pixel values in uniform area and available throughout the phantom, which is at vertebral foramen [1,2]. On standard mediastinum window settings (width : 350 and centre : 50) an ROI of 0.50 cm^2 was placed within the vertebral foramen. The SD measured in attenuation value HU is representing the image noise.

Data analysis

The data collected were analysed using the Statistical package for the Social Sciences (SPSS) version 21.0.The SPSS was used to conduct relevant statistical analysis of the measurement result and was selected mainly because of its proven track record as a highly software tool for statistical analysis in most research areas. Figure 4 shows the summary of the research methodology.

The thorax phantom PBH-50 was set into an AP position at the center of CT gantry

The scanning protocol has been set up according to departmental standard protocol of thorax examination. The first scanning has been done with ATCM activated

The scans were repeated with ATCM deactivated and tube current was set to 160 mA, 200 mA, 240 mA and 280 mA.

Radiation dose estimation of $CTDI_{vol}$ and DLP were recorded

Evaluation of CT image quality has been done by measuring the SD of the pixels values.

Figure 4. Summary of research methodology

III. RESULT & DISCUSSION

Table 3 shows a comparison of paired t-test on image quality between ATCM techniques and each selection of manual fixed tube current values. There were no significant differences for all four groups of comparison ($p > 0.05$).

Table 3. A comparison between ATCM and manual fixed tube current

Group Comparison	Mean (SD)	95% CI	t-statistic (df)	p-value
ATCM vs 160 mA	3.63 (2.23)	-1.29, 9.18	2.81 (2)	0.37
ATCM vs 200 mA	4.15 (0.73)	2.32, 5.97	9.78 (2)	0.32
ATCM vs 240 mA	5.39 (1.12)	2.62, 8.17	8.37 (2)	0.81
ATCM vs 280 mA	5.90 (0.57)	0.57, 4.49	17.99 (2)	0.23

Many studies have shown that the fixed mAs can result in higher radiation dose to the patient as there are wide variations of patient size and shape. ATCM was introduced to alter the value of mAS according to various sizes, volumes and shapes of object being scanned. It will increase the radiation dose literally (thicker or high attenuation part) and decrease it in the anteroposterior direction (thinner or low attenuation part) [3,4]. This system is designed to modulate the imparted radiation dose via changing of mAs on the basis of patient size and different attenuation. In other word, the mAs is increased in those parts of the body with highest attenuation (e.g shoulders) and diminished as the soft tissue attenuation decreases (e.g thorax), which in turn of overall radiation dose reduction for the patient. Without ATCM, image noise and radiation dose in an image would be primarily determined by those parts of the body with the highest soft tissue attenuation and the radiation dose to the patient would be significantly higher.
Rehani et all [5,6] in their study has shown that the most important tool used for patient dose reduction in CT scan is the prevention of unnecessary procedures and ATCM. They assert that multislice scanners can direct needlessly high doses if diagnostic request are not satisfactorily considered. The correct use of ATCM in CT is able to reduce absorbed doses around 50% and doses can vary between different institutions. Reduction in effective tube current product has been found with ATCM technique. There is 17% until 52% reduction in radiation exposure for thorax CT examination when performed using angular modulation technique compared with fixed tube current technique.

The objective of this study is to calculate the percentage of radiation dose reduction estimated in adult CT thorax examination with respect to $CTDI_{vol}$ and DLP between ATCM and manual selection of tube current. The final result of this comparison is shown in Table 4.

Table 4. Comparison of dose reduction between ATCM and manual tube current selection

Types of Scanning	$CTDI_{vol}$ (mGy)	DLP (mGycm)
ATCM	4.45	171

Types of Scanning (fixed tube current)	$CTDI_{vol}$ (mGy)	DLP (mGycm)	$CTDI_{vol}$ Increased (mGy)	$CTDI_{vol}$ Increased (%)
160 mAs	5.38	206	0.93	17.29
200 (mAs)	6.73	258	2.28	33.88
240 (mAs)	8.05	309	3.60	44.72
280 (mAs)	9.43	362	4.98	52.81

There are significant increases in $CTDI_{vol}$ and DLP for fixed tube current compared to ATCM. The measurements of CTDIvol represent the absorbed dose along the angular axis and CT radiation output. It is useful to compare between protocols, different scanner outputs as well as for quality assurance purpose. The $CTDI_{vol}$ value had been used for comparison across the institution in term of dose delivered by American College of Radiology Dose Index Registry.[5,7]. The protocol of CT thorax seems to be the second largest variation in term of dose delivered to the patient.[8, 9]. It shows that there is a lot of technique and preference from all over the institutions. One of the main objectives in this study is to emphasize the importance of ATCM technique for CT thorax protocol. The image quality and dose delivered to the patient is taken into consideration to ensure that the dose delivered to the patient can be reduced as much as possible.
Certain institution may be concern on the dose so the image produce may appear noisier as compared to other institution. However, the result shows that there is no significant difference for image quality between using ATCM technique and fixed tube current. Although no significant difference is shown, images acquired with ATCM technique had a higher noise compared with images acquired with fixed tube current.

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The results show that the exposure reduction around 17% till 52% can be achieved if the ATCM technique is applied in each scanning. In this study, the decrease pattern of dose from the application of ATCM technique will benefit the patient while the image quality is not affected.

IV. CONCLUSION

ATCM technique is recommended for the new reduction technique since the dose delivered to the patient can be reduced until 50% as compared to the fixed tube current (280 mA). The result in this study showed that the image quality for ATCM technique has no significance difference compare to manual selection of fixed tube current. ATCM technique promising and will benefit the patient with less radiation being delivered to them.

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