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Optimization of Radiation Dose during Cardiac Computed Tomography examinations using Phantom model

Tasneem S. A. Elmahdi*, SuhaibAlameen, Hussien Ahmed
Sudan University of Science and Technology, College of Medical Radiologic Sciences
P.O.Box 1908, Khartoum, Sudan
Corresponding Author: TasneemElmahdi

Abstract: *Radiation Dose Optimization for a Complete Cardiac Computed Tomography examination using Phantom Modelwere carried out at radiology department, king Fahad hospital, using computed Tomography scanner GE light speed VCT health care machine – 64 slice. Correlate between kVp with image quality using a person correlation and t-test to check the p.value were the spatial resolution, contrast resolution and noise level shows there is no significant difference between the image quality parameters and kVp were all values above 0.05.*

And correlate between the mAs and image quality parameters spatial resolution, contrast and noise level using person correlation and p.value, were the p.value shows there is no significant difference between the mAs and the image quality parameters, but the Pearson correlate show there is a significant difference between the contrast resolution and noise level with mAs per slice while the spatial resolution shows a no correlate with mAs per slice.

The helical pitch and scanning mode with image quality parameters using a Pearson and t-test, were the spatial resolution and the noise level shows no significant difference with helical pitch, while the Pearson correlate shows a reverse relation between the helical pitch and the contrast resolution. While the scanning mode were the spatial resolution give a 7 for helical and 6 for perspective gating, contrast resolution gives 2.3 for helical and 2 for prospective mode and the noise level 4.5 for helical and 5.8 for prospective mode. From the scanning mode here we notice that the helical mode is better than the prospective mode.

Keywords: *dose optimization, CATPHAN, phantom model, pitch*

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I. Introduction

CT is a powerful tool for the examination of chest disease because it can depict the disease process far more clearly than chest radiographs. Technical developments in CT scanners have enabled larger volume coverage with higher resolution and lower noise, but this has led to increased radiation exposure [1–4]. Coronary computed tomography angiography (CCTA) has evolved to an unprecedented rate during the last decade. It has become an effective and accurate tool for cardiac imaging with a growing list of clinical indications [5]. The detection of coronary disease in the investigation of atypical chest pain patients at low and intermediate risk with noncontributory functional tests is one of the main indications. CCTA is also useful for acute chest pain patients at low risk with normal electrocardiogram (ECG) And enzymatic cycle.

Studies in the United States, United Kingdom, Germany, and Japan have shown approximately twofold increases in the number of CT examinations performed between the late 1980s and the early 2000s [6–9]. The contribution of CT examinations to the collective dose from diagnostic radiation exposure is estimated to be 67% in the United States and 47% in the United Kingdom [6, 10]. Currently, the issue of radiation dose reduction draws wide attention. However, application of reduced-dose CT techniques in clinical practice varies among institutions [11,12], which illustrates the lack of a standard protocol for effectively reducing radiation dose to patients in clinical settings.

Because radiation dose is determined by many factors [13, 14], there are various ways to reduce the radiation dose in chest CT. CT scanning parameters that can be changed in clinical practice are summarized in Appendix 1.Lowering tube current or tube voltage is the most direct way of achieving radiation dose reduction. Because tube current is easier to modify and the result is more predictable, modification of tube current is most widely used. Tube voltage reduction is particularly useful when patient body diameter is small or when the contrast of target objects is high. Higher helical pitch can contribute to radiation dose reduction by reducing exposure time, although the effect on image quality depends on the type of scanner used. In axial scans, radiation dose is closely related to section thickness and section spacing. Individualization of scanning parameters can also reduce radiation dose through optimization of dose because patient size varies greatly. This is most important to avoid overexposure in the examinations of children and small adults [15].

In addition to radiation (ie, tube current and peak voltage), noise in the image is a function of scan time, pitch, section thickness, image reconstruction technique, and filtration, as well as the patient's size, shape, and anatomy. Image quality in smaller patients might improve with relative decreases in image noise and increases in SNR due to the smaller amounts of fatty tissue surrounding the internal organs; in larger patients, a higher noise level would be acceptable given the substantial amount of fatty tissue separating the organs [16].

Optimal SNR as a function of patient size for common diagnostic questions has not yet been defined, since there are no objective metrics for recording clinical opinions. *Tube current* is inversely proportional to noise in conventional filtered back projection (FBP) image reconstruction because it is directly proportional to the number of photons and the radiation dose. Increasing the tube current by a factor of four will quadruple the number of photons and the radiation dose, and will decrease the noise by one-half (inverse of 2, the square root of 4).

Scan time is the time it takes the gantry to make one revolution. The number of photons in the image is proportional to the scan time.Increasing the scan time will increase the number of photons delivered, thereby decreasing the noise and increasing the radiation dose. When IR techniques are used, this inverse relationship between noise and dose no longer exists. *Helical pitch* is the ratio between the distance the CT table travels during one gantry revolution and the detector width. Helical pitch is inversely related to the number of photons and the radiation dose.

II. Material and Methods

This study was carried out at radiology department, king Fahad hospital, using computed Tomography scanner GE light speed VCT health care machine – 64 slice General Electric's Multi-detector with serial NO 11803YC4. The Catphan phantom is generally used for the CT performance evaluation. The Catphan phantom is positioned in the CT scanner by mounting on the case which placed directly at the end of the table.

The Catphan 600 consists of 6 cylindrical parts located by precisely indexing the table from the center of section 1 (CTP 404) to the center of each subsequence test module.

Spatial Resolution module: The CTP528 high resolution module, this module it has 1 through 21-line pair /cm high resolution test gauge and two impulse sources (beads), which are cast into uniform material. The 21-line pair per centimeter gauge has Criteria of high contrast resolution is 6-line pair / cm.

Low – Contrast Resolution: The actual contrast levels will measure by making region of interest measurement over large target, and in the local background area. To determine the actual contrast level, average the measurement will make from several scans. It's important to measure the background area adjacent to the target, because of "cupping" and "capping" effect will cause variation in the CT number from one scan region to another. The module is contain three sets of discs with contrast of 0.3%, 0.5%, 1.0%, and the size of the discs are 2mm, 3mm, 4mm , 5mm , 6mm , 7mm , 8mm , 9mm , and 15mm.

Unfors CTDI phantom: This essential phantom consists of two parts: a body phantom and a head phantom. Both are made of solid acrylic, 15cm thick, with diameters of 32 cm and 16cm respectively. Each part contains five probe holes, one in the center and four around the perimeter, the inside diameter of the holes is 1.31 cm. Each part includes five acrylic rods for plugging all the holes in the phantom.**Unfors Ionization Chamber:** The ion chamber and electronics are combined into one unit making it possible to measure both temperature and pressure to actively compensate for the energy dependency**.**

Scanning parameters: The cardiac CT examination is one of the most common studies in the department. There are numbers of cardiac CT request for the scan. To start the process of cardiac scan protocol optimization, the hospital adult protocol for cardiac CT was used to scan a phantom (Catphan 600). Image quality evaluated from different parameters (image noise, spatial resolution and low contrast resolution. CT scan images quality was performed with different scanning parameters, tube voltage (kVp) and tube current (mA), pitch factor, slice thickness and collimation which have direct effects on the image quality and radiation dose. These parameters were varied and the results of this variation on the images were obtained.

Table 1. shows scan parameters for evaluation image quality and radiation dose:

Scan Parameters		Scan Parameters	
kVp	80, 100, 120,140	Rotation time (sec)	0.4, 0.5
mAs/slice	1000,900,800,700,600	Helical pitch	0.2, 0.24, 0.3
Scanning mode	Helical, Prospective Gating	Cardiac Dose right	ON, OFF
Collimation(mm)	64x0.625,40x0.625, 32x1.25	Slice thickness (mm)	0.68, 1.25

III. Results

In order to optimize the protocol, image qualities in terms of noise, spatial resolution and contrast to noise ratio were measured at the scanning parameters of kVp, mAs, pitch factor. Slice thickness and collimation change for two scan mode prospective gating and helical. The parameter having a good image quality accompany with the lowest dose will determined to be the optimal parameters.

Table 1. Correlation between kVp with Reconstruction parameters & Image quality:

Correlations		Spatial Resolution	Contrast Resolution	Noise Level
kVp	Pearson Correlation	0.945	0.967	0.852
	P-value	0.212	0.164	0.35

Table 2. Correlation between mAs/slice with Reconstruction parameters & Image quality

Correlations		Spatial Resolution	Contrast Resolution	Noise Level
mAs/slice	Pearson Correlation	0.866	-0.991**	0.987**
	P-value	0.058	0.001	0.002

** Correlation is significant at the 0.01 level

Table 3. Correlation between Helical pitch with Reconstruction parameters & Image quality

Correlations		Spatial Resolution	Contrast Resolution	Noise Level
Helical pitch	Pearson Correlation	0.918	-0.915	0.984
	P-value	0.260	0.265	0.115

Table 4. Compare mean between scanning mode with Reconstruction parameters & Image quality

Scanning mode	Spatial Resolution	Contrast Resolution	Noise Level
Helical	7.0	2.3	4.5
Prospective gating	6.0	2.0	5.8
Total	6.5 ± 0.7	2.1 ± 0.2	5.2 ± 0.9

Data express as Mean ± SD

Table 5. compare mean Collimation (mm) with Reconstruction parameters & Image quality

Collimation(mm)	Contrast Resolution	Noise Level
64 x 0.625	3.3	4.7
40 x 0.625	3.1	6.4
32 x 1.25	2.8	8.1
Total	3.1 ± 0.3	6.4 ± 1.7

Data express as Mean ± SD

IV. Discussion

Correlate between kVp with image quality using a person correlation and t-test to check the p.value were the spatial resolution, contrast resolution and noise level shows there is no significant difference between the image quality parameters and kVp were all values above 0.05.

Table 2. show the correlation between the mAs and image quality parameters spatial resolution, contrast and noise level using person correlation and p.value, were the p.value shows there is no significant difference between the mAs and the image quality parameters, but the Pearson correlate show there is a significant difference between the contrast resolution and noise level with mAs per slice while the spatial resolution shows a no correlate with mAs per slice.

Table 3. show correlate between helical pitch with image quality parameters using a Pearson and t-test, were the spatial resolution and the noise level shows no significant difference with helical pitch, while the Pearson correlate shows a reverse relation between the helical pitch and the contrast resolution.Table 4. show a correlation between the scanning mode with image quality parameters spatial and contrast resolution and noise level, were the spatial resolution give a 7 for helical and 6 for perspective gating, contrast resolution gives 2.3 for helical and 2 for prospective mode and the noise level 4.5 for helical and 5.8 for prospective mode. From the scanning mode here we notice that the helical mode is better than the prospective mode.

compare mean Collimation per mm with image parameters we using different three collimations for 64 x 0.625 the contrast resolution was 3.3 and the noise level 4.7, for collimation 40 x 0.625 and 32 x 1.25 the contrast resolution was 3.1 and 2.8 while the noise level was 6.4 and 8.1 respectively. From this table we notice that with increase the collimator diameter the contrast be better and the noise level decreased as shown in table 5.

V. Conclusion

Optimization of radiation dose for a Complete Cardiac Computed Tomography examination using Phantom Model were carried out at radiology department, king Fahad hospital, using computed Tomography scanner GE light speed VCT health care machine – 64 slice. Correlate between kVp with image quality using a person correlation and t-test to check the p.value were the spatial resolution, contrast resolution and noise level shows there is no significant difference between the image quality parameters and kVp were all values above 0.05.

And correlate between the mAs and image quality parameters spatial resolution, contrast and noise level using person correlation and p.value, were the p.value shows there is no significant difference between the mAs and the image quality parameters, but the Pearson correlate show there is a significant difference between the contrast resolution and noise level with mAs per slice while the spatial resolution shows a no correlate with mAs per slice.Correlate between helical pitch and scanning mode with image quality parameters using a Pearson and t-test, were the spatial resolution and the noise level shows no significant difference with helical pitch, while the Pearson correlate shows a reverse relation between the helical pitch and the contrast resolution. While the scanning mode were the spatial resolution give a 7 for helical and 6 for perspective gating, contrast resolution gives 2.3 for helical and 2 for prospective mode and the noise level 4.5 for helical and 5.8 for prospective mode. From the scanning mode here we notice that the helical mode is better than the prospective mode.

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