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Assessment of Image Qualityand Dose Optimization During Cardiac Computed Tomography Examination Using Catphan Phantom Model

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

ABSTRACT:the aim of this study to Assessment of Image Quality and Dose Optimization during Cardiac Computed Tomography examination using Catphan Phantom model, were the study carried out at radiology department, king Fahad hospital, using computed Tomography scanner GE light speed VCT health care machine – 64 slice.The correlation between kVp with spatial resolution and contrast resolution, and measure the dose length product and computed tomography dose index volume, were the contrast resolution, DLP and CTDIvol was increase almost linearly with increasing the kVp, but the spatial resolution was 6 lp/cm with 80 kVp while the 100, 120 and 140 kVp gives same value 7lp/cm. And correlation between mAs with spatial resolution and contrast resolution, and measure the dose length product and computed tomography dose index volume, for spatial resolution gave 6 lp/cm for the mAs from 600 to 800 and 7 lp/cm for 900 and 1000 mAs. And the relation between the mAs with the contrast resolution was reversely with increase the amber the contrast decrees. While the DLP and CTDIvol was increasing with increase the mAs.
The relation between the pitch and spatial resolution, contrast resolution, DLP and CTDIvol, were the spatial resolution with pitch gave 6lp/cm for 0.2 and 0.24 and 7 lp/cm for 0.3, and the contrast resolution was decrease with increase the pitch, the DLP and CTDI vol was increase with increase the helical pitch. For scanning mode, we discuss two type helical and prospective gating, the helical mode give a 7lp/cm for spatial resolution and 2.31 for contrast while prospective gating mode give a 6 lp/cm and 1.96 for contrast. For compare which one is better we briefer the helical for the spatial and contrast resolutions while the prospective mode briefer for the dose for the patients.

Keywords: spatial resolution, contrast resolution, CATPHAN, Noise

I. INTRODUCTION

Cardiac imaging is an invaluable tool in the diagnosis and management of heart disease. As a consequence of new capabilities and widespread availability, the use of medical imaging has increased dramatically in the United States, as has radiation exposure related to imaging. The National Council on Radiation Protection & Measurements reports that the total radiation exposure to the US population from medical imaging has increased 6-fold since 1980, even though the radiation doses from individual examinations have stayed approximately constant or decreased. Nearly 40% of this medical radiation exposure to the US population (excluding radiotherapy) is

Related to cardiovascular imaging and intervention [1]. A recent American Heart Association Science Advisory outlined a conceptual framework for understanding radiation exposure from cardiac imaging, including the risks related to exposure to ionizing radiation, and provided general recommendations for the safe use of cardiac imaging that relies on ionizing radiation [2].

Image quality is a nonspecific term used to describe the overall “goodness” or specific characteristics of an image. CT image quality is usually classified on the basis of accuracy (in terms of Hounsfield units), spatial resolution, noise, low contrast detectability, and artifacts.

Spatial resolution relates to how well the features of small objects are preserved in the image. The low-contrast detectability demonstrated by a CT system is very important because it is a measure of the ability to identify low-contrast features at a low radiation dose. The International Electro-Technical Commission [3] recommends the expression of the quality of CT images in terms of objective physical tests as measures of diagnostic performance of a system. These measures include: uniformity, linearity and measures of the detective quantum efficiency of the imaging system using psychophysical evaluation.

Spatial resolution: Spatial resolution (SR) is the ability of an imaging system to differentiate objects in the two spatial dimensions of an image e length and width. SR measures the ability of a system to distinctly delineate two objects as they become smaller and closer together. The closer they are together with the image still showing them as separate, the better the SR. SR depends on the reconstruction matrix; detector width; slice thickness; object to detector distance; focal spot and matrix size [4]. The resolution properties of an imaging system are described by the modulation transfer function (MTF). The MTF describes the percentage of an object's contrast that is recorded by the imaging system as a function of its size (spatial frequency).

Contrast resolution: Contrast resolution (CR) of an imaging system determines the contrast detail that can be visibly reproduced when there is a small difference in density relative to the surrounding area, implying that subtler objects can be seen on the image. CR is highly degraded by noise. To reliably identify a structure, the signal to noise ratio (SNR) needs to be better than 5:1. This requirement is known as Rose's criterion, described by Albert Rose, a scientist working on early television systems. The SNR is thus the best descriptor of CR which is easily determined from measurements of regions of interest within the test object and surrounding noise. [4,5]

Noise: Noise in CT is the degree of uncertainty in the measurement of the attenuation of the x-ray beam passing through the patient. This uncertainty should not be so great as to influence the presentation of the resultant image. Noise in CT depends on the number of x-ray photons falling on the detectors referred to as quantum noise and is the most important factor affecting the quality of the image. Quantum noise is the statistical fluctuation or standard deviation of CT numbers of a homogeneous region of interest. Quantum noise is measured by calculating the standard deviation from the mean HU over an area 10% of the cross-sectional area of a test object. A standard range for noise for spiral CT scanners is _ 4HU [6-8]. The number of photons reaching the detectors is determined by the milli-ampere seconds (mAs) while their energy is determined by the kilo-voltage (kV). Decreasing the mAs and kV increases image noise but reduces patient dose. A 50% reduction in mAs produces a 40% increase in noise degrading image contrast, but with a 50% dose reduction [8]. Noise is also inversely proportional to the square root of the dose and slice thickness [9,10]. Several points must be considered regarding CT radiation dose. First, there is an argument that radiation exposure in medical imaging has a significant impact on cancer risk related to radiation exposure. It is reported that exposure to ionizing radiation during diagnostic imaging may be responsible for 0.6–3.2% of malignant tumors in 15 developed countries [11], and CT examinations are responsible for most of the collective patient dose, So the main aim of this study is to optimize the dose during cardiac CT examination using Catphan phantom model**.**

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

Image Quality Measurements: The first image quality parameter to be evaluated is the noise; it was calculated from the uniformity module within the phantoms. Circular region of interest (ROI) of 5 cm^2 in unit of Hounsfield Unit (HU) was used to take measurement of the mean CT number and standard deviation, which recorded from the center of the image. **The second parameter** was spatial resolution (SR), which was evaluated by the numbers of the line pairs that was seen through the 21-line pair pattern; demonstrate on the scanned image of Catphan phantom. **The third parameter** was low contrast resolution in term of Contrast to Noise Ratio (CNR), the CNR was calculated from 1.0% level of contrast in low contrast resolution module and it was measured by making region of interest over the largest target and in the local background area. The mean CT number (intensity) and standard deviation (noise) for the target (t) and in the local background (b) area were recorded, the mean CT number of the background was subtracted from the mean CT number of the target area and the result was divided by the standard deviation (noise) of the background as in the equation:

CNR = mean CT number (t) – mean CT number (b) / SD b

The phantom was scanned in prospective gating and helical mode. The displayed CTDIvol was recorded from the computer console for each scan parameters. The Catphan®**600** was re – scanned with lowering the scan parameters including kVp, mAs, slice thickness, collimation and pitch factors.

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. Radiation dose in terms of CTDIvol and DLP recorded for each measurement. The parameter having a good image quality accompany with the lowest dose will determined to be the optimal parameters**.**

The following tables shows correlation between the image quality parameters, scan parameters and reconstruction parameters

Table .1Evaluation of spatial resolution with variation in kVp number:

kVp	**Spatial resolution /MTF**	**Contrast resolution**	**DLP (mGy- cm)**	**CTDI vol (mGy)**
80	6lp/cm	2.35	368	9.2
100	7lp/cm	2.91	476	11.9
120	7lp/cm	3.62	580	14.5
140	7lp/cm	3.95	602	15.3

Table .2 Evaluation of spatial resolution with variation in mAs/slice:

mAs/ slice	Spatial resolution /MTF	Contrast resolution	DLP (mGy- cm)	CTDI vol (mGy)
600	6lp/cm	3.08	368	9.2
700	6lp/cm	2.76	388	9.7
800	6lp/cm	2.66	400	10
900	7lp/cm	2.34	420	10.5
1000	7lp/cm	2.07	452	11.3

Table .3 Evaluation of spatial resolution with variation in helical pitch:

Helical pitch	Spatial resolution/ MTF	Contrast resolution	DLP (mGy- cm)	CTDIvol (mGy)
0.2	6 lp/cm	2.91	500	12.5
0.24	6 lp/cm	2.61	508	12.7
0.3	7 lp/cm	2.52	576	14.4

Table 4. Evaluation of spatial resolution with mode of scan:

Scanning mode	Spatial resolution/ MTF	Contrast resolution	DLP (mGy- cm)	CTDI vol (mGy)
Helical	7 lp/cm	2.31	612	15.3
Prospective gating	6lp/cm	1.96	34.4	0.86

Table 5. Evaluation of spatial resolution with variation in slice thickness:

Slice thickness (mm)	Spatial resolution/ MTF	Contrast resolution	DLP (mGy- cm)	CTDI vol (mGy)
0.68	7 lp/cm	3.08	548	13.7
1.25	6 lp/cm	2.67	496	12.4

IV. DISCUSSION

Correlate between kVp with spatial resolution and contrast resolution, and measure the dose length product and computed tomography dose index volume, were the contrast resolution, DLP and CTDIvol was increase almost linearly with increasing the kVp, but the spatial resolution was 6 lp/cm with 80 kVp while the 100, 120 and 140 kVp gives same value 7lp/cm as shown in table 1.

Table 2. Show correlation between mAs with spatial resolution and contrast resolution, and measure the dose length product and computed tomography dose index volume, for spatial resolution gave 6 lp/cm for the mAs from 600 to 800 and 7 lp/cm for 900 and 1000 mAs. And the relation between the mAs with the contrast resolution was reversely with increase the amber the contrast decrees. While the DLP and CTDIvol was increasing with increase the mAs.

The relation between the pitch and spatial resolution, contrast resolution, DLP and CTDIvol, were the spatial resolution with pitch gave 6lp/cm for 0.2 and 0.24 and 7 lp/cm for 0.3, and the contrast resolution was decrease with increase the pitch, the DLP and CTDI vol was increase with increase the helical pitch as shown in table 3. For scanning mode we discuss two type helical and prospective gating, the helical mode give a 7lp/cm for spatial resolution and 2.31 for contrast while prospective gating mode give a 6 lp/cm and 1.96 for contrast. For compare which one is better we briefer the helical for the spatial and contrast resolutions while the prospective mode briefer for the dose for the patients as shown in table 4.

Table 5. shows the slice thickness per mm related to spatial and contrast resolutions and DLP, CTDIvol, were the thickness 0.68 mm give 7 lp/cm for spatial resolution and 3.08 for contrast resolution while the thickness 1.25 give 6 lp/cm for spatial resolution and 2.67 for contrast resolution for the dose measurements the thickness 1.25 looks better for both the dose length product and computed tomography dose index.

V. CONCLUSION

Assessment of Image Quality and Dose Optimization during Cardiac Computed Tomography examination using Catphan Phantom model, were the study 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 spatial resolution and contrast resolution, and measure the dose length product and computed tomography dose index volume, were the contrast resolution, DLP and CTDIvol was increase almost linearly with increasing the kVp, but the spatial resolution was 6 lp/cm with 80 kVp while the 100, 120 and 140 kVp gives same value 7lp/cm.

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***Corresponding Author: Tasneem Elmahdi**
Sudan University of Science and Technology, College of Medical Radiologic Sciences,
P.O.Box 1908, Khartoum, Sudan*