International Journal of Science and Research (IJSR)
ISSN: 2319-7064
SJIF (2019): 7.583

Effects of Scan Parameters on Patients Radiation Dose in Multi-Slice Helical CT Scan

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Abstract: ***Computed tomography (CT) has established itself as a primary diagnostic imaging modality, the number and impact of clinical applications of CT have continued to grow. Understanding of a few basic CT scan parameters is essential, and knowledge of how to manipulate these parameters to produce diagnostic images at lower doses is critical for safe imaging.The aim of this study was to recognize the relation between the patient radiation dose and adjustable scan parameters in stander routine CT head protocol using multi-slice helical CT scanner.***

Keywords: CT, mA, kVp, Pitch ,$CTDI_{VOL}$, DLP

1. Introduction

Since its introduction in 1973, x-ray computed tomography (CT) has established itself as a primary diagnostic imaging modality [1]. Subsequent to the introduction of helical scanning technique in the late 1980s [2, 3] and the advent of multidetector-row technology in the late 1990s [4], the number and impact of clinical applications of CT have continued to grow [5]. Computed Tomography imaging benefits to the practice of medicine are certain but alarms regarding increased cancer risk from CT continue to worsen. Last several years scientists are concern about the importance of reducing radiation dose in radiological studies, specifically with regard to multi-detector CT scan [6]. However, since the cancer risk associated with the radiation dose in CT is not zero, it is clear that reducing radiation dose in CT must continue to be one of the top imports of the CT community, particularly in light of the continuous increase in the number of CT examinations performed annually.

Understanding of a few basic CT scan parameters is essential, and knowledge of how to manipulate these parameters to produce diagnostic images at lower doses is critical for safe imaging [7]. Two guiding principles must be followed, firstly CT examinations must be appropriately justified for each individual patient [8], secondly, for each CT examination, all technical aspects of the examination must be optimized, such that the required level of image quality can be obtained while keeping the doses as low as possible [9].

When facing increasing censure regarding CT dose, the best way to challenge the issue is to understand all the factors and parameters that can affect radiation dose and image quality and examine how these can be changed to reduce dose [7].

The radiation exposure to patients undergoing CT examinations is determined by two factors: equipment-related factors, i.e. the design of the scanner with respect to dose efficiency, and application-related factors, i.e. the way in which the radiologist or the radiographer makes use of the scanner [10]. Radiologists must accept the primary responsibility for minimizing radiation dose to patients, how to apply dose reduction strategies in CT, and must know how to interpret radiation dosimetric data available on a CT dose report and understand the effects of CT technical parameters on patient radiation exposure [6].

Radiation dose in CT can be quantified in a variety of ways. Scanner radiation output, organ dose and effective dose are some of the more common dose metrics. The scanner radiation output is currently represented by the volume CT dose index (CTDIvol), expressed in milligrays, which describes the radiation output of the scanner in a very standardized way, making use of two standardized acrylic phantoms [11]. Simplistically, CTDIvol can be considered the average radiation output per slice of the CT scanner and depends only on the type of scanner and acquisition parameters such as x-ray tube peak kilovoltage (kVp) and tube current–time product (mAs). It is independent of patient size and scan length [12]. The CTDIvol is displayed on the CT console just before the patient is scanned and can be used to alert the operator that the protocol should be modified if the CTDIvol is judged excessive for that particular study [13]. The dose length product DLP, expressed in milligrays × centimeters (mGy × cm), is the product of the CTDIvol (mGy) and scan length (cm). It represents the integrated dose over the length of the exposure and reflects the total amount of radiation incident on the patient. Although the numeric values of the CTDIvol and DLP are critical for dose management, it is important to comprehend that these dose metrics are not a direct measurement of patient dose; they are a standardized dose metric to represent scanner output levels, when measured in a standardized phantom. Effective dose, typically expressed in the units of millisievertmSv, is a quantity representing a ‘whole-body equivalent’ dose that would have a similar risk of health detriment as that due to a partial body irradiation [14]. Effective dose allows an approximate comparison of radiation-induced risk among different types of examinations. An estimate of the effective dose can be calculated from the DLP by taking the product of the DLP and a body part–specific conversion factor (k) [15]. So there are three dose descriptors in all, which everyone dealing with CT should be familiar with [16].

Radiation dose is one of the most significant factors determining CT image quality and thereby the diagnostic accuracy and the outcome of a CT examination, soradiation dose should only be reduced under the condition that the diagnostic image quality is not missing. Therefore, to understand how the radiation dose in CT can be reduced, it is necessary to be familiar with the relationship between image quality and radiation dose [5].

Scanning parameters that consequence on CT radiation dose include the x-ray tube current expressed in milliamperes (mA), tube current–time product expressed in milliampere-seconds (mAs), x-ray tube peak voltage (kVp), x-ray tube rotation time (exposure time), helical pitch, reconstructed slice thickness, image noise, automatic exposure control (AEC), and noise-reducing image reconstruction algorithms [6].

2. Materials and Methods

This study was conducted at Najran University laps of Radiological Sciences Department in the 2019-2020 academic year, and was aimed to recognize the relation between the patient radiation dose and adjustable scan parameters. In this study we used scenario CT scanner from Hitachi, it is a multi-detector machine with 64 raw of detector each raw is 0.625 mm width. Also we use a whole body phantom to apply the protocols, the parameters influencing patient dose were evaluated. Radiation dose indicators CTDIvol and DLP are displayed in scanner monitor.

Technique

We apply the standard protocol of routine head helical scan, the measured radiation dose to the phantom was assessed for five parameters on multi-slice helical CT system we experienced, the parameters which were selected for this study were tube current (mA), tube voltage(Kv), pitch, slice thickness and field of view. Absorbed dose (CTDIvol and DLP) for this protocol was taken as standard measurement. Then the protocol is repeated with changing of only one parameter and setting other parameters. Whenever we change any parameter we read the CTDIvol and DLP. Finally we compare every radiation dose with the standard protocol reading.

3. Results

The measurements of radiation dose obtained by apply the standard protocol of routine head helical scan using scenariamultislices CT scanner from Hitachi in radiology sciences department at Najran University, were summarized in below tables:

Table 1: Radiation Dose Measurement for standard protocol parameters in Multislice Helical CT

Scan parameter	Standard value	CTDIVOL	DLP
mA	175	48.5 mGy	1.12Gy.cm
Kv	120		
Slice thickness	5mm		
Pitch	0.5781		
FOV	220		

Table 2: Radiation Dose Measurement for Varying tube current (mA) in Multislice Helical CT

mA	CTDI mGy	DLP mGy.cm
175	48.5	1120
150	41.6	961.8
125	34.7	801.5
100	27.7	641.2
87.5	24.3	561.1
200	55.5	1280
225	62.4	1440
350	97.0	2240

Table 3: Radiation Dose Measurement for Varying tube peak voltage (kVp) in MultisliceHelical CT

kV	CTDI mGy	DLP mGy.cm
120	48.5	1120
100	31.3	723.1
80	16.6	385.0
140	69.2	1600

Table 4: Radiation Dose Measurement for Varying Slice Thickness in Multislice Helical CT

S/ Th mm	CTDI mGy	DLP mGy.cm
5	48.5	1120
2.5	48.5	1120
0.625	48.5	1120
7.5	48.5	1120
10	48.5	1120

4. Discussion

The aim of this study was to recognize the relation between the patient radiation dose and adjustable scan parameters in Multislice Helical Computed Tomography imaging.

Table 5: Radiation Dose Measurement for Varying Pitch in Multislice Helical CT

PITCH	CTDI mGy	DLP mGy.cm
0.5781	48.5	1120
0.8281	33.9	785.5
1.0781	26.1	671.1
1.3281	21.1	561.1
1.5781	17.8	448.8

Table 6: Radiation Dose Measurement for Varying Field of View (FOV) in Multislice Helical CT

FOV	CTDImGy	DLP Gy.cm
220	48.5	1120
170	48.5	1120
120	48.5	1120
270	48.5	1120
320	48.5	1120

Table (1) represented $CTDI_{VOL}$ and the DLP in standard helical protocol, it was recognized 48.5 mGyand 1.12 Gy\cm respectively. In this protocol the tube current was 175 mA, tube voltage was 120 kV, slice thickness was 5 mm, pitch was 0.5781 and field of view was 220 mm.

Table (2) shown the effect of Tube current (mA) on radiation dose, it was reflect the changed in the radiation dose with decreased only mA and all other parameters were unchanged, so when decreased the tube current to 150 mA (14.3%) as in standard protocol, the $CTDI_{\mathbf{VOL}}$ was decreased to 41.6 mGy (14.2 %), while the DLP was decreased to

961.8 mGy\cm (14.1 %),with decreased the tube current to 125 mA (28.6%), the $CTDI_{VOL}$ decreased to 34.7mGy (28.5 %), while DLP decreased to 801.5 mGy\cm (28.4 %),when we decrease the tube current to 100 mA (42.9%), the $CTDI_{VOL}$ decreased to 27.7mGy (42.9 %), while DLP decreased to 641.2 mGy\cm (42.8 %),and when decreased the tube current to 87.5 mA (50 %), the $CTDI_{VOL}$ decreased to 24.3mGy (49.9 %), and DLP decreased to 561.1 mGy\cm (49.9%). But When we increased the tube current to 200 mA (14.3%) with other parameters still unchanged, the $CTDI_{VOL}$ increased to 55.5mGy (14.4 %), DLP increased to 1.28 Gy\cm (14.3%),with increased the tube current to 225 mA (28.6%), the $CTDI_{VOL}$ increased to 62.4mGy (28.7 %), DLP increased to 1.44 Gy\cm (28.6 %),and with increased the tube current to 350 mA (100 %), the $CTDI_{VOL}$ increase to 97.0mGy (100 %), while DLP increased to 2.24 Gy\cm (100 %). Linear association between decreasing and increasing tube current (mA) and $CTDI_{VOLand}$DLP were found.

Increases in tube current or the product of tube current and scan time (mAs) result in improved image quality, decreased image noise, and increased patient dose (18). Saini S. principles and practice for abdominal applications. Radiology 2004, state that In general, the relationship between tube current and patient dose is essentially linear, with increases in mAs resulting in an equivalent percentage increase in patient dose [17]. The usage of the automatic exposure control (AEC), which is automatically modulate the tube current to accommodate differences in attenuation due to different patient parts is best practice .

Table (3) Reflects the effect of kVp on radiation dose, with decreased the tube voltage to 100 kV (16.7 %) and other parameters still as in standard protocol, the $CTDI_{VOL}$ decreased to 31.3mGy (35.5%), DLP decreased to 723.1 mGy\cm (35.4%), decreased the tube voltage to 80 kV (33.3 %), the $CTDI_{VOL}$ decreased to 16.6mGy (65.8%), DLP decreased to 385.0 mGy\cm (65.6 %). And with increased the tube voltage to 140 kV (16.7 %), the $CTDI_{VOL}$ increased to 69.2mGy (42.7%), while DLP increased to 1.6 Gy\cm (42.9 %). Decreasing the KVP to 100 kv result in decreasing the $CTDI_{VOL\ and}$ DLP by 35.5%,this was considerable effect in reduction patient dose. The relationship of dose to kVp is more complicated, Reducing kVp can be an effective means of reducing the radiation dose imparted during an examination. Study done by Gnannt R, et al,2012 found that the radiation dose changes with the square of kVp, and a reduction in kVp from 120 to 100 reduces radiation dose by 33%, while a further reduction to 80 kVp can reduce dose by 65% [15-18].

Table (4) shown the effect of Slice Thickness on radiation doseand represent that with decreased the slice thickness to 2.5 mm (50 %) , and to 0.625 mm (87.5 %) without changing in other parameters as in standard protocol, the $CTDI_{VOL}$ and DLP were not affected. And When we increased the slice thickness to 7.5 mm (50 %) and to 10 mm (100 %) with other parameters unchanged as in standard protocol, the $CTDI_{VOL}$ and DLP also not affected. Many studies conceive that the slice thickness with MDCT does not directly affect radiation dose, but if all other factors are held constant, thinner reconstructed slices produce noisier images [6]

Table (5) shown the effect of Pitch on radiation dose and t demonstrate that when we increased the pitch to 0.8281 (43.2%) and to 1.0781 (86.5%) with other parameters unchanged as in standard protocol, the $CTDI_{VOL}$ decreased to 33.9mGy (30.1%), and to 26.1 mGy (46.1%), while DLP decreased to 785.5 mGy\cm (29.9 %) and 671.1 mGy\cm (40.0%) respectively. And when we increase the pitch to 1.3281 (129.7%) and 1.5781 (173%) with other parameters unchanged as in standard protocol, the $CTDI_{VOL}$ decreased to 21.1mGy (56.5%), and 17.8mGy (63.3%), while DLP decreased to 561.1 mGy\cm (49.9%) and 448.8 mGy\cm (59.9 %) respectively. we found that, if all other parameters are unchanged, increasing pitch reduces radiation dose in a linear manner in the Hitachimulit-slice helical CT systems under the test. But Mahesh, Mahadevappa, et al suggest that the strategy of increasing pich for radiation dose reduction on single-slice helical CT scanned may not be safely applied to all mulit-slice helical CT systems, and to maximize the clinical benefit of multi-slice helical CT ,while limiting the radiation dose , radiologist and physicist must acquire a thorough , machine –specific understanding of the multi-slice equipment of chosen manufacture[19].

Table (6) represent Radiation Dose Measurement for varying Field of View (FOV) in Multislice Helical CT**,** when we decrease the FOV to 170 mm (22.7%) and 120 mm (45.5%) with other parameters stable as in standard protocol, the $CTDI_{VOL}$ and DLP not affected. And with increased the FOV to 270 mm (22.7%) and 320 mm (45.5%) with other parameters fixed as in standard protocol, the $CTDI_{VOL}$ and DLP also not affected. We suggest no relation between patient dose and Varying Field of View (FOV).

The reduction level of radiation dose, anatomical structure and clinical indication are different for each individual patient. In order to use the minimum radiation dose to achieve a reasonable diagnostic image quality, the scanning techniques must take into account all of these patient-specific factors.

5. Conclusion

Reduction of radiation dose is the regulatory principle for a medically indicated CT examination. In this study some multidetector CT parameters can be changed to reduce radiation dose, including tube current mA, kVp, and pitch. Technologists must understand the information in the CT dose report and know the effects of crucial CT technical parameters on patient radiation exposure, the proper use of these technical parameters is critical to achieve the reduction of radiation dose during multi-slice helical CT examination. In our study no consequence of scan field of view and slice thickness in patient dose. Further study is recommend to find out the impact of the slice thickness in radiation dose, and to compare between the image quality and change of scan parameters.

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