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Original Article

Optimization of Parameters in 16-slice CT-scan Protocols for Reduction of the Absorbed Dose

Shahrokh Naseri[1], Mahdi Momen Nezhad[1], Zahra Hozhabri[2*], Abbas Haghparast[2], Golestan Karami[2], Peyman Hejazi[3]

Abstract

Introduction
In computed tomography (CT) technology, an optimal radiation dose can be achieved via changing radiation parameters such as mA, pitch factor, rotation time and tube voltage (kVp) for diagnostic images.
Materials and Methods
In this study, the brain, abdomen, and thorax scaning was performed using Toshiba 16-slice scannerand standard AAPM and CTDI phantoms. AAPM phantom was used for the measurement of image-related parameters and CTDI phantom was utilized for the calculation of absorbed dose to patients. Imaging parameters including mA (50-400 mA), pitch factor (1 and 1.5) and rotation time (range of 0.5, 0.75, 1, 1.5 and 2 seconds) were considered as independent variables. The brain, abdomen and chest imaging was performed multi-slice and spiral modes. Changes in image quality parameters including contrast resolution (CR) and spatial resolution (SR) in each condition were measured and determined by MATLAB software.
Results
After normalizing data by plotting the full width at half maximum (FWHM) of point spread function (PSF) in each condition, it was observed that image quality was not noticeably affected by each cases. Therefore, in brain scan, the lowest patient dose was in 150 mA and rotation time of 1.5 seconds. Based on results of scanning of the abdomen and chest, the lowest patient dose was obtained by ۱۰۰ mA and pitch factors of 1 and 1.5.
Conclusion
It was found that images with acceptable quality and reliable detection ability could be obtained using smaller doses of radiation, compared to protocols commonly used by operators.
Keywords: Computed Tomography (CT), Absorbed dose, Optimization.

1- Medical Physics Dept., Mashhad University of Medical Sciences, Mashhad, Iran
2- Medical Physics Dept., Kermanshah University of Medical Sciences, Kermanshah, Iran
*Corresponding author: Tel: +9809159102408; Fax: +9805136642600; E-mail: z.hozhabri213@yahoo.com
3- Medical Physics Dept., Semnan University of Medical Sciences, Semnan, Iran

1. Introduction

In recent years, computed tomography (CT) technology has undergone profound changes. Compared to single-section CT, multi-detector row computed tomography (MDCT) has some specific scan parameters, which enable the systematic increase or decrease of radiation dose to patients and facilitate the visualization of micro-anatomic structures of the temporal bone. MDCT systems have the potential to decrease the radiation dose, but the actual dose reduction depends on how the system is used [1].

The improved diagnostic capabilities arising from MDCT technology have resulted in the increasing application of CT examinations, which account for a significant portion of radiation dose, received from all medical procedures [2].

Increasing awareness about the adaption of exposure factors such as over ranging, over beaming, tube voltage (kVp), effective mA, pitch factor, and scan lengthcan contribute to the management of radiation dose to patients [1].

Dose levels imparted in CT exceed those of conventional radiography and fluoroscopy. In fact, CT application continues to grow, often by 10 -15% per year [3].

Rapid technical advances in CT technology have contributed to the increased number of clinical indications. Unfortunately, exposure to radiationhas consequently increased due to the elevated number of CT examinations.

Over the past few years, various studies have demonstrated the feasibility of radiation dose reduction for CT examinations without compromising image quality or reducing detection accuracy [4].

Although radiation may be associated with adverse effects, it serves an important function in diagnostic imaging. Radiologists are responsible for finding a safe dose range for each patient, given that radiation should be minimized for safety and maximized for diagnostic quality [5].

To be compliant with the principle of “as low as reasonably achievable (ALARA)”, it is necessary to justify CT examinations beforehand. In this respect, radiologists should play an important advisory role in the process of decision making with referring clinicians. When equal or enhanced diagnostic yield is expected, CT-scan should be replaced by alternative imaging modalities (with no or less ionizing radiation) such as sonography, magnetic resonance (MR) imaging, or radionuclide voiding cystography.

Radiologists should make an effort to reduce the radiation dose of CT examinations, while maintaining the diagnostic quality when CT is indicated. A straightforward method to achieve this goal is minimizing the scan range of CT examinations, as required[6].

2. Materials and Methods

Modern CT scanners provide two dose parameters which became available by scanner manufacturers around 2001. These two parameters are volume computed tomography dose index (CTDIvol) reported in units of mGy, and dose-length product (DLP) measured in mGy-cm. CTDIvol is a measure of the average dose within the scan volume for standardized phantoms. Also, the total amount of radiation delivered to a standardized phantom is represented by DLP, which is the product of CTDIvol and scan length.

Organ absorbed doses in CT are substantially below the threshold doses for the induction of deterministic effects (e.g., erythema, epilation). Therefore, there is a risk of radiation-induced carcinogenesis for the patients[6].

An estimate of effective dose, which is associated with carcinogenic risk, may be obtained by using effective dose per unit dose length product (E/DLP) conversion factors. Although effective doses for CT are significantly higher than those of conventional radiography, they are comparable to those associated with interventional fluoroscopy, diagnostic coronary catheterization, and nuclear medicine examinations. Although the risk associated with CT examination is small, it is not zero. Hence, CT examinations should be performed only when a net patient benefit is anticipated. In addition, the amount of radiation should always follow the ALARA principle [5].

In this study, measurements were performed by a 16-slice Toshiba CT-scanner. CT imaging parameters including mA, rotation time, and pitch factor, as independent variables, were changed at specified intervals, while image quality parameters including spatial resolution (SR) and contrast resolution (CR), as dependent parameters, and dose in length patient (DLP), as a dose-dependent parameter, were being monitored.
The CT divice was adjusted in 120 kVp, and slice thickness was 4 mm. Scanning was performed in the brain, chest, and abdomen. By changing mA, pitch factor, and rotation time, while considering a lower limit of image quality parameters, reduction in patient dose parameters was determined.

2.1. Brain scan procedure

Brain scaning was performed with multi-slice mode . Rotation time and mA were effective parameters, unlike pitch factor. Therefore, changes of mA and rotation time were considered.
At this stage, imaging was performed under two conditions. Firstly, mA was changed in the range of 50, 100, 150, 200, 250, 300, 350, and 400, and the rotation time was fixed at 1.5s. Secondly, mA was set to 150 and the rotation time varied in the range of 0.5, 0.75, 1, 1.5 and 2 s.

2.2. Abdomen and thorax scanning procedures

Abdomen and thorax scanning was performed in the spiral (helical) mode. Given the limited scan time, rotation time was determined as 0.5s. Thus, only two parameters of mA and pitch factor were altered in this scan.
The images were obtained under two different conditions. First, the pitch factor was set to 1, and then, it was set to 1.5. In both conditions, the values of mA were selected to be 50, 100, 150, 200, 250, 300, 350, and 400.
In this study, two types of phantom were used. The first one was American Association of Physicists in Medicine (AAPM) phantom (Figure 1), (model 610, made in the United States), which was used for measuring SR and CR.

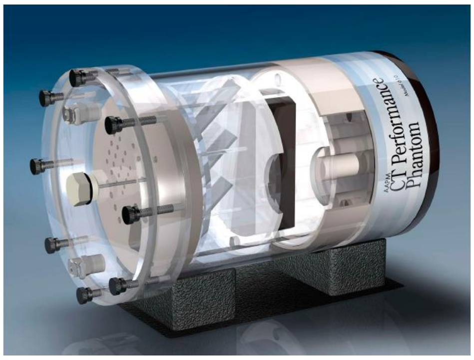

Figure 1. AAPM phantom [3]

The second type was computed tomography dose index CTDI phantom, used along with a pencil dosimeter chamber (Figure 2) (10 cm in length), which measured the patient dose. Also, the associated tools with dosimeter were (manufactured by RTI Inc., Sweden).

Figure 2. CTDI phantom and pencil dosimeter chamber [8]

The dosimeter was placed in different parts of the phantom for measuring the exposure dose. The result was recorded by the handheld computer screen.Obtained images were read and depicted by MATLAB software (7.8 version, 2009) and analyzed by the associated commands.
The obtained images were pixelated by MATLAB, and the intensity of each pixel was demonstrated in a matrix. Relevant data in the region of interest (ROI) were analyzed (Figure 3) and the related point spread function (PSF) diagrams were obtained.
It should be mentioned that PSF is the most basic measure of resolution properties of an imaging system, and perhaps the most intuitive, as well. A point source is the input to the imaging system, and the PSF is (by definition)

the response of the imaging system to that specific input. PSF is also called the 2D impulse response, and is typically described in x and y dimensions of a 2D image [PSF (x, y)] [9].

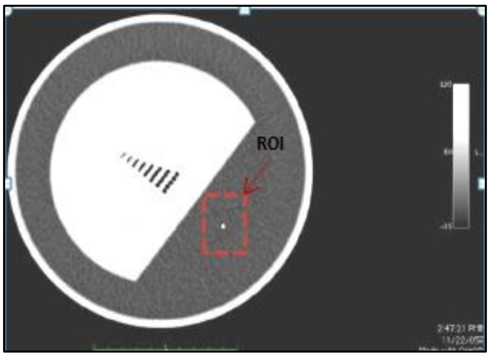

Figure 3. ROI for computing PSF

The pixel with maximum intensity in ROI was determined, and then, the PSF plot was drawn as the following diagram (Figure 4).

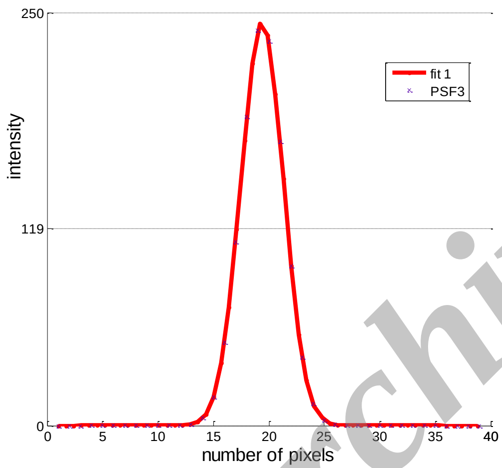

Figure 4. A sample plot of PSF

After normalizing the PSF data, spatial resolution or full width at half maximum (FWHM) was obtained. CR was taken with the help of a radiologist (Figure 5).

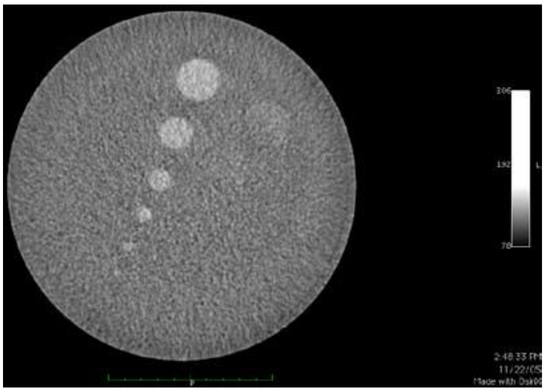

Figure 5. The picture of AAPM phantom for measuring CR

These images were evaluated by a physician and CR was subjectively evaluated. This optical diagnostic method was compared with spatial resolution graphs, and images with proper quality were tested for dose determination.

3. Results

In this study, optimization of protocols for reducing patient doses in brain imaging, was performed. The rotation time was changed and mA was fixed at 150 (FWHM=2.8 mm). Thus, the lowest patient dose at 150 mA and rotation time of 1.5s was obtained.

Then, the amount of mA was changed and the rotation time was fixed at 1.5s (FWHM=2.8 mm). Therefore, the patient dose with mA of 150 and the rotation time of 1.5s was minimal under these condition. In order to optimize the protocols for reducing patient doses in the thorax and abdomen scans, two procedures were followed.

Firstly, the pitch factor was fixed to 1 (in a constant state) and mA was changed; no significant alteration in the CR and SR of images was observed (FWHM=2.1 mm). As the results indicate, the pitch factor of 1 and mA of 100 in the abdomen and thorax imaging delivered the lowest dose for the patient.

Secondly, pitch factor was set to 1.5 and mA was changed. The obtained CR and SR of the images underwent significant changes (FWHM=2.1 mm). Thus, patient doses can be minimized by setting mA and pitch factor to 100 and 1.5, respectively.

4. Discussion

It is necessary to mention that this method of imaging has not been done yet, therefore, comparison between the results of this study and others completely is not possible.

In order to compare spiral mode with multi-slice mode, the absorbed dose for the brain was measured in both cases. Based on results, the dose in the spiral mode was much higher (almost double) than multi-slice mode in brain imaging.

Reduction of kVp and current tube led to reduce radiation dose [4]. But due to the high amount of images, kVp was adjusted in the average volume of 120.

Considering the size of brain, compared to thorax and abdomen, the obtained dose was too high. However, 350mA and 400mA were disabled on the device, since the radiologist was not allowed to use these high doses in brain scanning.

Imaging conditions can affect the absorbed dose. At 120 mA, the patient dose in pitch factor of 0.685 was optimizad [1]. In spiral imaging of the abdomen and thorax, the absorbed dose increased linearly and directly with mA in pitch factors of 1 and 1.5 ,as expected.

It should be noted that images obtained with mAs of 50, 150, 250, and 350 contain high amounts of noise due to discrepancies and inconsistencies in the original configuration of 16-slice CT scanner. Therefore, these amounts were removed and only mA values of 100, 200, 300, and 400 were considered. As the specialist and image processing with MATLAB indicated, images with acceptable quality and reliable detection ability can be obtained using lower radiation doses than the protocols commonly used by operators.

5. Conclusion

In CT technology, patients may receive very high doses of radiation with no significant alteration in image quality. Considering other studies [1,2,4,5] and comparing their data with this study, it can be concluded that changes in modifiable and important factors such as mA while maintaining image quality, the patient dose can be reduced.

Optimization of parameters for each divice and each method of imaging is different. It was found that images with acceptable quality and reliable detection ability could be obtained using smaller doses of radiation, compared to protocols commonly used by operators.

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