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Original Article

Investigation of the Computed Tomography Number of Blood, Fat, and Water in Different Levels of Kilovoltage and Reconstruction Kernels

Shouresh Ehsanbakhsh[1], Salman Jafari[2*], Safoora Nikzad[3]

[1]School of Medicine, Hamadan University of Medical Sciences, Hamadan, Iran
[2]Department of Radiology Technology, School of Paramedicine, Hamadan University of Medical Sciences, Hamadan, Iran
[3]Department of Medical Physics, School of Medicine, Hamadan University of Medical Sciences, Iran

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***Corresponding author:**
Salman Jafari,
Email: sa.jafari@umsha.ac.ir

Abstract

Background: A computed tomography (CT) scan is an imaging modality with many clinical applications. The CT number of different materials plays an important role in the accurate diagnosis of the disease and reduction of errors. Other factors, such as kilovoltage (kVp) and reconstruction kernels, may have an effect on CT numbers. The aim of this study was to investigate the impact of different levels of kVp and kernels on the CT number of the blood, fat, and water.

Methods: In this cross-sectional study, the CT numbers of the blood, fat, and water were investigated at 80 kVp, 110 kVp, and 130 kVp, as well as H31, H70, J30, and U90 reconstruction kernels using a 16-slice CT scanner (Siemens). The scanning of each material was repeated three times, and the mean CT number of each substance was extracted from the device software. The Kruskal-Wallis statistical test was used to compare CT numbers between different levels of kVp and reconstruction kernels.

Results: The results showed that the mean CT numbers of the blood, water, and fat were 55, -4.2, and -102 Hounsfield unit (HU). No significant difference was observed between the CT numbers of water, fat, and fresh blood at 80 kVp, 110 kVp, and 130 kVp ($P>0.05$). In addition, the difference in the CT number of fresh blood, water, and fat in reconstruction kernels H31, H70, J30, and U90 was not significant ($P>0.05$).

Conclusion: It was revealed that the CT number of water, fat, and blood does not change significantly with kernel and kVp, and this can help specialists in diagnosis.

Keywords: CT scan, X-Ray, Blood, Fat, Water, CT Number

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Introduction

Computed tomography (CT) scanning is widely used in diagnostic imaging (1). This method provides cross-sectional images from humans. Hence, the internal parts of the body can be observed without overlapping (2). An X-ray tube coordinated by a detector rotates surrounding the patient, and the computer calculates the attenuation coefficient of tissues (3). Subsequently, the CT number is computed from the attenuation coefficients of water and tissues as follows (4):

$$CT\ number = \frac{\mu - \mu_{water}}{\mu_{water}} \times 1000 \qquad (1)$$

Where μ and μ_{water} represent the attenuation coefficients of material and water, respectively.

Finally, CT numbers are displayed as grey levels scaled by the mapping function to obtain an image with a good contrast (5).

The CT number depends on the amount of radiation absorbed by the material. For example, fat tissue absorbs less radiation than muscle tissue. Any parameter that has an impact on the radiation absorption coefficient is effective on CT number, and kilovoltage (kVp) is one of these influential factors (6).

In the CT scan, the linear attenuation coefficient for each pixel is calculated by the reconstruction algorithm and then converted to a CT number. Hence, this algorithm is important in the calculation of the CT number and may affect the CT number. This subject has been claimed by Ohno et al in a Quantitative Imaging Biomarker Alliance (QIBA) phantom study on the effects of the acquisition method and the reconstruction algorithm for CT number measurement on standard- and reduced-dose CT. They investigated the influence of three reconstruction algorithms (i.e., filtered back projection, adaptive iterative dose reduction using 3D processing, and forward projected model-based iterative reconstruction) on the CT number (7).

Reconstruction kernels and kVp are two variables in scanner software. Technicians select these parameters considering the intended pathology and tissue. Given the above explanations, the CT number is a highly important factor on which the accurate diagnosis is dependent. This study sought to investigate the effect of kVp and kernels on the CT number of blood, fat, and water.

Materials and Methods

This cross-sectional study was conducted in Hamadan from October 2020 to March 2022. The researchers scanned a water phantom, a piece of beef fat, and fresh blood under different acquisition conditions using a 16-slice CT scanner (Siemens). First, a topogram image was taken, and the scan box was adjusted to the intended material. Scanning was performed in the sequential mode. Three kVp levels available on the device (i.e., 80 kVp, 110 kVp, and 130 kVp) were applied to track the changes in the CT number due to kVp. Each scan was repeated three times. In addition, images were reconstructed by different reconstruction kernels, including H31, B70, and U90. Next, the images were loaded in the image review environment, and the CT number was measured by drawing a region of interest with a diameter of 2 cm. The average CT number inside the circle and its standard deviation were extracted for each scan and recorded as the CT number and noise. The obtained data were analyzed using SPSS software. The Kruskal-Wallis statistical test was utilized to check the significance of the difference between CT numbers in different conditions.

Results

Scan Parameters

Scanning parameters for water, fat, and blood, including kVp, tube current (mAs), scan time, reconstruction kernel, section thickness, and collimation, are summarized in Table 1.

CT Number of Water, Fat, and Blood in Different Kilovoltage Levels

CT numbers of water, fat, and blood at 80 kVp, 110 kVp, and 130 kVp are provided in Table 2. Based on the results, the average CT number decreased by increasing the voltage, but the difference was not significant between 80 kVp, 110 kVp, and 130 kVp for all materials ($P > 0.05$).

CT Number of Water, Fat, and Blood in Different Reconstruction Kernels

The results obtained for the CT number of water, fat, and blood with H31, B70, and U90 reconstruction kernels are presented in Table 3. The differences in CT numbers for all the intended materials between reconstruction kernels were not significant ($P > 0.05$).

Discussion

Technological advances in multidetector CT have led to lower dose protocols with improved image quality.

Table 1. Scan Parameters Used in This Study

Material	kVp	Reconstruction Kernel	mAs	Slice Thickness (mm)	Collimation (mm)
Water-fresh blood-fat	80	H31	60	1.5	16×0.6
	80	B70	60		
	80	U90	60		
	110	H31	40		
	110	B70	40		
	110	U90	40		
	130	H31	20		
	130	B70	20		
	130	U90	20		

Note. kVp: kilovoltage; mAs: Milliampere-seconds.

Table 2. CT Number of Water, Fat, and Blood at 80 kVp, 110 kVp, and 130 kVp

Material	kVp	CT Number (Mean ± SD)	*P* Value
Blood	80	59.9 ± 6.3	0.39
	110	53.5 ± 4.7	
	130	54.4 ± 3.9	
Fat	80	-115.4 ± 23.9	0.3
	110	-98 ± 17.1	
	130	-94.1 ± 15.2	
Water	80	6.5 ± 5.37	0.58
	110	3.9 ± 1.98	
	130	2.2 ± 1.62	

Note. kVp: kilovoltage; CT: Computed tomography; SD: Standard deviation.

Table 3. CT Number of Water, Fat, and Blood at Different Kernels

Material	Kernel	CT Number (Mean ± SD)	*P* Value
Blood	H31	58.8 ± 2.5	0.16
	B70	50.1 ± 10.8	
	U90	58.9 ± 1.6	
Fat	H31	-100 ± 5.8	0.24
	B70	-102.1 ± 17.04	
	U90	-105.3 ± 33.4	
Water	H31	3.9 ± 2.6	0.67
	B70	3.4 ± 1.76	
	U90	5.2 ± 2.4	

Note. CT: Computed tomography; SD: Standard deviation.

Further advances have increased the number of CT scans performed per year. Usually, the difference between the measured CT numbers is much less than the magnitude of the acceptable ranges for each material (8,9).

In the present study, the CT number of blood was higher than that of water and fat. The results revealed that the average CT number decreased with increasing the tube voltages, but this reduction was not significant. The reason for small changes in the CT number with kVp is that the attenuation coefficient of the material is changed with changing the kVp. Changes in kVp affect the quality of the beam, and other factors such as the filters used in the device and the stability of the detector also have an effect on this issue. In the study by Okayama et al, the average CT number increased with increasing energy in oil, while it decreased in the contrast medium. In addition, for the tissues, the average CT number for the left ventricular cavity, myocardium, and vertebral bone was the highest for 40 kVp and decreased with increasing energy. Therefore, the effective energy used in imaging can affect the CT number of different tissues (10). In the study performed by Krup et al, the CT number of solid water and air in Toshiba scanners was significantly higher than that of Siemens. The CT number of polyethylene and acrylic increases with increasing kVp. The CT number of bone-equivalent tissue decreased with increasing kVp (11), which is consistent with the results of the present study.

The results showed that CT numbers of blood, water, and fat were nearly the same with different reconstruction algorithms, but noise increased when the degree of kernel increased from soft to sharp. Afif et al also investigated the relationship between the electron density of tissues and the CT number and observed that kVp had a significant effect on the ratio of electron density to the CT number. These changes increased by increasing the voltage from 70 to 100 and from 120 to 140, but the changes were not significant (12).

Conclusion

Based on the findings, the CT number of water, fat, and blood did not change with a change in the kernel and kVp. This issue can greatly help radiologists in the field of detecting these substances in CT scan images.

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Authors' Contribution

Conceptualization: Salman Jafari.
Data curation: Shouresh Ehsanbakhsh.
Formal analysis: Safoora Nikzad.
Funding acquisition: Salman Jafari.
Investigation: Shouresh Ehsanbakhsh.
Methodology: Salman Jafari.
Project administration: Salman Jafari.
Resources: Salman Jafari.
Software: Salman Jafari.
Supervision: Salman Jafari.
Validation: Shouresh Ehsanbakhsh.
Visualization: Safoora Nikzad.
Writing–original draft: Salman Jafari.
Writing–review & editing: Salman Jafari.

Competing Interests

There is no conflict of interests.

Ethical Approval

This study was approved by the Research Ethics Committee of Hamadan University of Medical Sciences (IR.UMSHA.REC.1399.597).

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