ANALYSIS OF THE EFFECT OF CARE DOSE 4D SOFTWARE USE ON IMAGE QUALITY AND RADIATION DOSE ON THE CT SCAN ABDOMEN

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ABSTRACT

The CT Scan is the most significant contributor to radiation dose on radiological examination, although the frequency of the examination is far below other modalities. In order to control this radiation dose, manufactures of CT Scan have equipped their units with built-in software called Automatic Exposure Control (AEC). This study aims to analyze the effect of AEC software, CARE Dose 4D, on image quality, and CTDIvol. Objects used in this study were three water phantoms, each with a diameter of 165 mm, 230 mm, and 305 mm. The image quality-analyzed was CT Number and noise. Measurement of image quality was carried out following Bapeten's provisions. Noise Power Spectrum (NPS) graphics were also used to further observes noise texture. The CT Number accuracy, CT Number, and noise uniformity obtained with and without CARE Dose 4D, on the three phantoms were still within Bapeten's threshold. This indicates that the use of CARE Dose 4D can still image a homogeneous object accurately. The results of the NPS curve showed that the two modes, in three phantoms, were having the same noise texture. The NPS curves also showed that the use of CARE Dose 4D produces higher noise than the non-CARE Dose 4D mode. Meanwhile, there were significant differences from the CTDIvol obtained from the two modes. The use of CARE Dose 4D software reduced dose of up to 54.34%. From this, the use of CARE Dose 4D software can reduce the radiation dose while maintaining image quality.

Keywords: CT Number, CTDIvol, noise, noise power spectrum

INTRODUCTION

The use of a CT scan in the radio-diagnostic examination is increasing. There were 13 million CT scans in the United States in 1990 and tripled to around 46 million 10 years later [1], and increased to 62 million in 2006 [2]. CT Scan accounts for the largest dose of radiation reception compared to other radiological examinations. Radiation generated on CT scans contributes 60% of radiological examinations, although the frequency of examinations is only 7% of complete examination [3]. The radiation dose received by the patient on a CT scan is 1-14 mSv depending on the type of examination to be carried out, proportional to the annual dose received from natural radiation sources, such as radon and cosmic radiation (1-10 mSv) depending on where a person lives [4].

Manufactures of CT Scan unit have done optimization by presenting an Automatic Exposure Control (AEC) system in the form of built-in software to reduce the radiation dose. Each manufacture's AEC systems were designed for different purposes but mainly works by modulating the tube current to compensate for variations in attenuation of the patient's body, with a different method of operator control [5,6]. Reductions in radiation dose inevitably result in a corresponding reduction in image quality. Tube current value affects the image quality, especially noise. The higher the tube current, the more number of photons is produced, thereby reducing quantum noise [7]. Therefore, users must possess a good understanding of their CT Scans' AEC systems in order to achieve dose reduction and optimal diagnostic image. An early version of CARE Dose software for pelvic CT showed that the system lowers 32% of the calculated CTDIvol with no significant loss in signal to noise ratio [8]. Evaluation of CARE Dose 4D along with other CT Scan's AEC systems showed that, for the anthropomorphic chest phantom, dose reduction with AEC mode were ranging from approximately 35% to 60%, and z-axis image noise also becomes more uniform compared to the non-AEC mode [9].

Computed tomography of the abdomen and pelvis (CTAP) has become a first-line imaging method for many conditions, such as including abdominal trauma, acute abdominal pain, suspected abdominal abscess and inflammation, and in the detection and surveillance of neoplastic conditions. The image quality can, however, be limited by the patient's body build, image noise, suboptimal contrast enhancement, motion, and aliasing/blooming artifacts [10]. Therefore, it is important to evaluate whether the use of AEC in an abdominal CT Scan affects the image quality. In this study, we focused on evaluating CARE Dose 4D in reducing radiation dose and its effect on image quality of CT Number accuracy, CT Number, and noise uniformity, alongside noise texture for abdominal CT Scan.

METHOD

This study aims to analyze the effect of the use of the AEC system on a CT scan unit on image quality and CTDIvol doses. The AEC system is the default CT Scan unit software that automatically adjusts the tube current (mA) according to variations in attenuation in the patient's body [5]. AEC adjusts attenuation at different parts when the tube surrounds the

patient on the x and y axes and adjusts attenuation along the anatomical part of the patient's body. Thus different patient sizes will result in adjustments to the different radiation doses [11] - [13]. The current modulation of the tube can be seen in FIGURE 1.
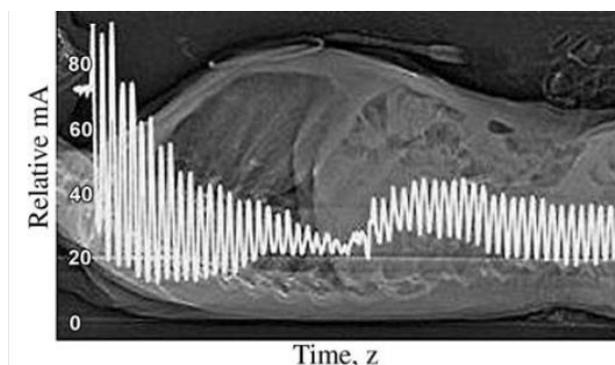
FIGURE 1. Graph of how AEC works in modulating tube current as a function of time (table position along the z-axis) [6]

The AEC system evaluated in this study was CARE Dose 4D software from the 16-slice Siemens Somaton emotions CT Scan. The imaging object used was three solid water phantoms, each with a diameter of 165 mm, 230 mm, and 305 mm. The scanning parameter settings used can be seen in TABLE 1.

(a)   (b)
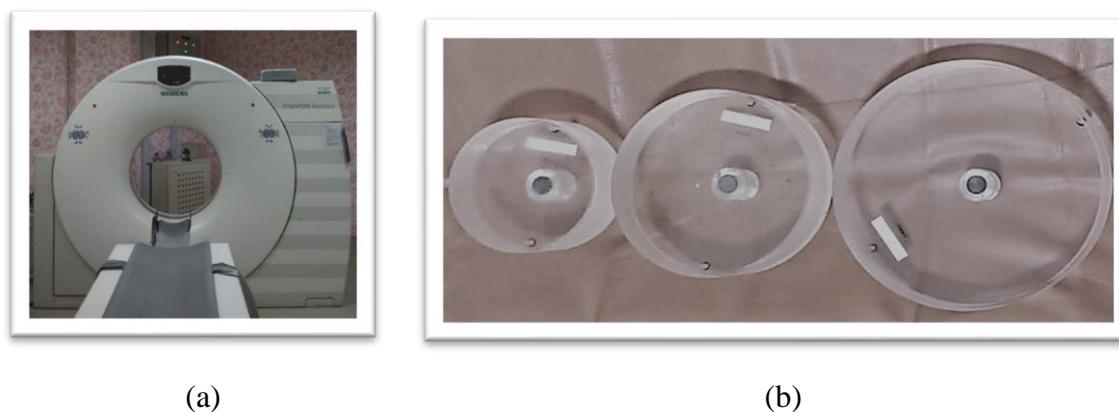
FIGURER 2. Research Tools. (a) CT Scan Siemens Somaton Emotions 16, (b) solid water phantom pf various diameters.

The image quality-analyzed is the accuracy and uniformity of CT Number and noise uniformity. CT Number is the value of the network attenuation coefficient relative to the water attenuation coefficient. CT Number varies, where the value of the CT water number is zero. The noise itself is a variation from the CT Number value. Noise is usually assessed by calculating the standard deviation of the image. Evaluation of image quality is carried out in accordance with Bapeten's recommendations in Perka Bapeten no. 2 of 2018 concerning the Conformity Test of Diagnostic and Interventional X-ray Radiology. CT Number accuracy measurement is done by making ROI (Region of Interest) in the center of the image. The

uniformity of CT Number is measured by finding the difference between the CT Number value on the ROI at the edge and the center of the image. Meanwhile, the uniformity of noise is measured by finding the difference in the standard deviation of the ROI on edge with the center of the image. ROI placement for noise measurement can be seen in FIGURE 2. ROI number 1-4 is the edge of the image. ROI number 5 is the center of the image.


| (a) | (b) |
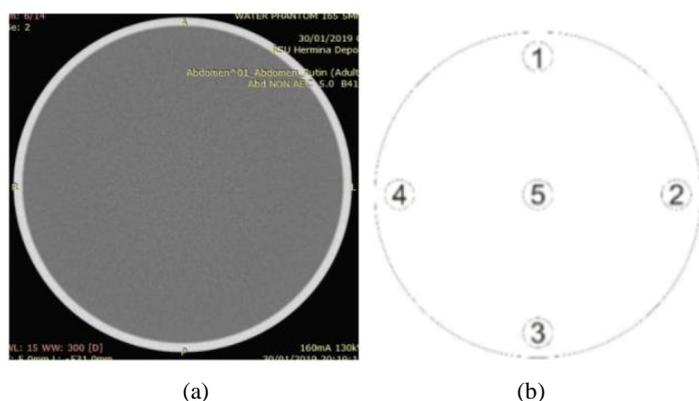
FIGURE 3. Measurement of CT Number and Noise. (a) Image examples, (b) ROI measurement points

Noise Power Spectrum (NPS) graphics are also used to further observe noise textures. NPS is a more complete description of noise than simple standard deviation. Not only able to describe the amount of noise, but NPS also describes the variation of noise as a function of spatial frequency so that it can describe the texture of noise. When combined with variable doses, it can be used for comparisons between scanners and protocols and has proven useful in translating protocols from one CT Scan platform [11]. NPS (f), for 2D images I (x, y) 2, can be formulated in EQUATION (1).

$$NPS(f_x, f_y) = \left| \int_x \int_y [I(x, y) - I] e^{-2\pi i(xf_x + yf_y)} dx dy \right| \tag{1}$$

where f_x is the frequency corresponding to the dimension x and f_y is the frequency corresponding to the dimension y, and I is the average CT Number of the image.

The number of doses observed in this study was CTDIvol. CTDI or Computed Tomography Dose Index is a method of calculating the patient's average dose at one scan. CTDIvol is a measure of the average dose along the scan volume of a specific standard phantom. For adult abdomen examinations, a standard phantom has a diameter of 32 cm. The estimated CTDIvol value used is the value indicated on the CT Scan console monitor.

TABLE 1. Setting Scanning parameters with and without CARE Dose 4D.

Scanning Parameter	Non CARE Dose 4D	CARE Dose 4D
kV	130	130
mA		
Water Phantom 165 mm	120	25 – 120
Water Phantom 230 mm	120	45 -120
Water Phantom 305 mm	120	92 - 120
Slice Thickness (mm)	5	5
Scan Time (sec)	0.6	0.6
Field of View (mm)	300	300
Pitch Factor	0.8	0.8
Reconstruction Algorithm	B41s	B41s

RESULT AND DISCUSSION

Measurements of CT Number accuracy, CT Number uniformity, and noise uniformity were performed on the 6th slice image sample, which is the best visual image. CT Number and noise measurements are performed on the CT Scan workstation by making ROI at the center of the image, and four edge points clockwise, which is 12, 3, 6, and 9. The average HU value on the ROI is CT Number, while the standard deviation value is the noise value. The results of CT Number accuracy measurements can be seen in TABLE 2. Based on these data, CT Number values, both obtained with or without CARE Dose 4D Software from the three diameter variations, nothing exceeds the Bapeten threshold, that is, still within the range - $4 \leq$ CT $\leq +4$. This value shows that the use of CARE Dose 4D Software still produces accurate CT Number values, especially water.

TABLE 2. CT Number accuracy values with and without CARE Dose 4D.

Phantom Size (mm)	Mode	Average Central CT Number	Threshold	Conclusion
165	CARE Dose 4D	-0.4	$-4 \leq$ CT $\leq +4$	Passed
	Non CARE Dose 4D	-0.4		
230	CARE Dose 4D	-0.5		
	Non CARE Dose 4D	-1.0		
305	CARE Dose 4D	0.6		
	Non CARE Dose 4D	-0.4		

The measurement results for CT Number uniformity and noise uniformity can be seen in TABLE 3. Based on these data it is seen that in general the maximum difference between the average edge and center CT in CARE Dose 4D images is greater than Non CARE Dose 4D images, but all of them do not exceed the specified threshold by Bapeten, which is $\leq \pm 2$ CT. This means that the use of CARE Dose 4D Software is still able to produce images of uniform objects well, and has a large uniform noise at all positions.

TABLE 3. CT Number and Noise uniformity values with and without CARE Dose 4D.

Mode	Phantom Size (mm)	Maximum Difference in Center CT & Edges	Maximum Standard Deviation of Edge CT & Edge	Threshold	Conclusion
CARE Dose 4D	165	1.2	0.9		
	230	1.7	1.0	$\leq \pm 2$ CT	
	305	1.8	1.2		Passed
Non CARE Dose 4D	165	0.4	0.6		
	230	0.7	1.0	$\leq \pm 2$ CT	
	305	-0.8	1.0		

Furthermore, to evaluate deeper noise, the Noise Power Spectrum (NPS) method is also performed. Noise evaluation using the NPS method is intended to assess the amount of noise (noise level) and texture of the noise itself. Noise can be seen broadly below the NPS chart. While noise textures can be seen in peak spatial frequency values. Low frequency spatial indicates rough noise texture, while high frequency spatial indicates smooth noise texture.

The NPS graph for each phantom with two modes can be seen in FIGURE 3. It can be seen in both modes, that the larger the phantom size, the greater the area under the NPS graph. This shows that the larger the phantom size, the greater the noise. When compared the two modes, the NPS curve with CARE Dose 4D mode has an area under the graph that is larger than the non CARE Dose 4D mode. This shows the noise level of using CARE Dose 4D is greater than without CARE Dose 4D. Both are in accordance with the evaluation of noise using standard deviations that have also been carried out.

(a)   (b)
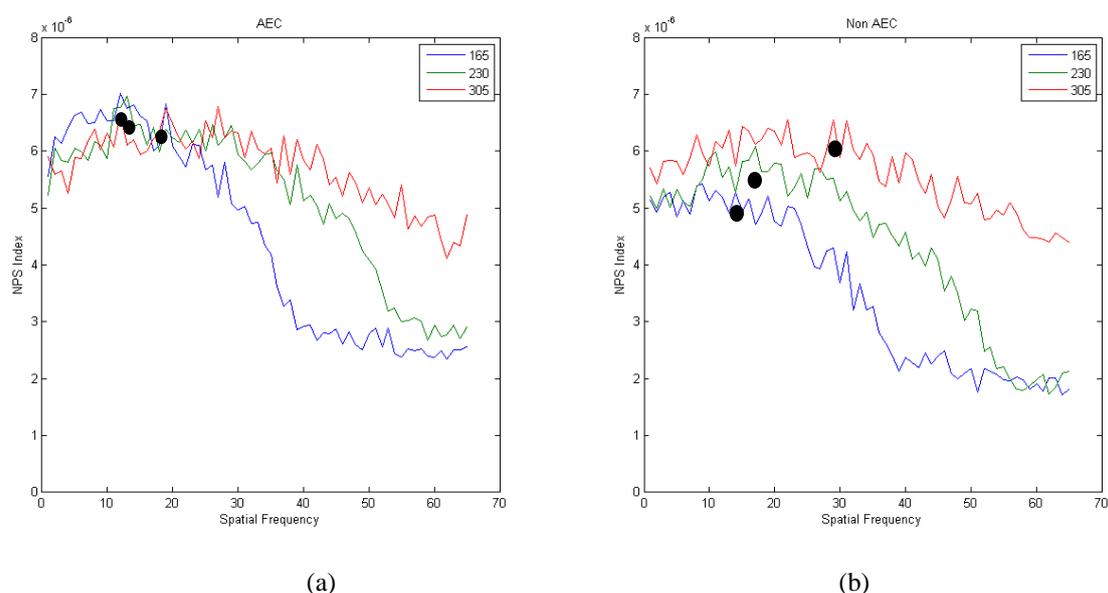
FIGURE 4. NPS Curve (a)CARE Dose 4D Mode, (b)Non CARE Dose 4D Mode.

Noise texture variations that can be seen peak spatial frequency values (marked with •). In general, CARE Dose 4D and non CARE Dose 4D images produce almost the same form of noise (texture noise), i.e. the spectrum has peaks at low spatial frequencies, which means the resulting noise texture is roughly shaped. If we look at the spatial peaks of frequency at all three phantom sizes, it can be seen that the spatial frequency peaks at the size of 165 mm and 230 mm are almost the same, which means they produce almost the same noise texture. While the phantom size of 305 mm has a larger spatial frequency peak, which means the texture of the resulting noise is smoother.

Based on this it can be seen that CARE Dose 4D images contain greater noise than non CARE Dose 4D images. This is one of them caused by differences in the use of tube current (mA) in the two modes. Non CARE Dose 4D mode uses fixed mA, while CARE Dose 4D mode uses modulated mA (varies in each slice) The mA value affects many photons produced. Noise in radiological images is largely a quantum noise, the magnitude of which is influenced by the frequency of photons that come to the object, so the value of mA affects the level of noise in an image.

TABLE 4 shows the CTDIvol values with CARE Dose 4D and non CARE Dose 4D modes. Based on the table it can be seen that the CTDIvol value in non-CARE Dose 4D mode is the same in all phantom sizes. Meanwhile, CTDIvol with CARE Dose 4D mode has a different value. The larger the phantom size, the greater the CTDIvol value. When compared, the use of CARE Dose 4D can reduce the value of CTDIvol up to 54.34%. This shows that the CTDIvol value only depends on the tube current value (mA) [6]. CARE Dose 4D Mode uses modulated mA to produce a lower dose of CTDI radiation.

TABLE 4. CTDIvol values with and without CARE Dose 4D.

	Phantom Diameter (mm)					
	Non CARE Dose 4D			CARE Dose 4D		
	165	230	305	165	230	305
CTDIvol (mGy)	12.22	12.22	12.22	2.6	4.66	9.47
Average CTDIvol (mGy)	12.22			5.58		

CONCLUSION

CT Number accuracy, CT Number, and Noise uniformity, both in CARE Dose 4D and Non-CARE Dose 4D modes, are still at the Bapeten threshold. Noise evaluation with NPS shows that using CARE Dose 4D produces more noise than Non-CARE Dose 4D, but both produce almost the same noise texture. Based on the CTDIvol evaluation, it can be seen that the use of CARE Dose 4D can reduce the radiation dose up to 54.34%. This shows that the use of the AEC CARE Dose 4D system is very useful in reducing the radiation dose without any affecting CT Number and noise. However, since high-quality diagnostic images are needed in an abdominal CT Scan, it's best to also evalutes the effects of the AEC system in other image quality parameters, such as spatial resolution and contrast.

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