Imaging Using Digital Radiography on Fat Network Phantom for Obesity Condition Correction

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Abstract: ***X-rays have been widely used in medicine such as diagnosis. The interaction of X-rays with tissues is the basis of diagnostic imaging techniques. Image contrast depends on the nature of the attenuation of the mass and thickness of the tissue in the body. This is a problem in obese patients. This study aims to determine the correction factors for obesity conditions and obtain contrast improvements in imaging using digital radiography. The measurement object uses a standard phantom that is used as a reference, then added artificial fat tissue phantom with a thickness of 2.5 and 8 cm, with a density value of 0.9 g / ml equal to fat tissue in the body. X-ray irradiation is carried out using digital radiography aircraft with variations of 90 - 117 KV and 125 & 200 mAs and at a distance of 150 cm. The parameters kV, mAs and distance produce radiation intensity values. The researcher uses the Contrast-limited adaptive histogram equalization (CLAHE) method with a correction factor α in the exopnential equation. From this research, the result of correction factor of fat tissue phantom to standard phantom at 125 mAs is 1,402 for thickness of 2 cm, 1,832 for thickness of 5 cm and 2,079 for thickness of 8 cm, at 200 mAs for 2,243 for thickness of 2 cm, 2,932 for thickness of 5 cm and 3,328 at a thickness of 8 cm. After the Clahe method the error value at 125 mAs with α = 0.4 at 2 cm thickness is 0.94, α = 0.6 at 5 cm thickness at 0.86 and α = 0.6 at 8 cm thickness at 1.3 while at 200 mAs with α = 0.8 at 2 cm thickness of 0.48, at a thickness of 5 cm at 2.35 and at a thickness of 8 cm at 2.5.***

Keywords: X-rays, CLAHE, Fat tissue, image contrast, radiation dosimetry

1. Introduction

X-rays are electromagnetic radiation that has been widely used in medicine such as diagnosis. One diagnosis using X-rays is digital radiography. Digital Radiography (Digital Radiography) is an imaging diagnostic modality by applying X-rays. Differences from other radiographs, digital radiography can produce images in digital form that can be shown on a monitor screen. The challenge in imaging diagnosis is to produce good image quality. One of the parameters of image quality is image contrast. The results of radiographic images show contrast is a gray scale (greyscale) which shows the nature of biological tissue. Image contrast is influenced by the nature of the tissue when interacting with X-rays. The interaction of X-rays and tissue including absorption, scattering and deflection is the main basis of this application. Absorption and scattering by tissue is determined by the coefficient of mass attenuation and tissue thickness. These two parameters will affect the absorption of X-ray energy. This is because the mass attenuation coefficient depends on the network density and the network attenuation coefficient. Both of these coefficients affect the energy absorption associated with X-ray dosimetry. Tissue in the body is divided into two namely soft tissue and hard tissue. The problem with radiographic techniques is to differentiate each tissue in the body such as fat tissue. Fat tissue (adipose) is soft tissue in the body that can be found in the skin and internal organs.

Determination of X-ray dosimetry is determined by body weight and size. This BMI standard becomes the main basis in determining dosimetry. However, this standard determination still cannot produce good image quality because it is influenced by complex tissue properties such as fat tissue. Fat tissue in obese patients has attenuation characteristics that are different from normal patients. What can be done as a solution is to improve X-ray dosimetry. However, increasing dosimetry will reduce image contrast. An appropriate dosimetry adjustment method is needed according to the ALARA concept.

The determination of X-ray dosimetry in this study cannot be carried out using patients because X-rays with large energy can be dangerous. For that, it is done using phantom. Phantoms are generally imitations or biological body models. Phantom material that can approach fat tissue is polyethelene. Polyethelene material is a thermoplastic polymer material because the boiling point ranges from 105 oC to 135 oC depending on the density of polyethelene. For this reason, polyethelene is often used as a tissue phantom material. It aims to determine the correlation of X-ray dosimetry on the thickness of fat tissue phantom.

2. Research Methods

The research procedure consists of several stages carried out from beginning to end to achieve the objectives of this study. The research procedure involved making fat phantom for correction of obesity conditions.

Making Phantom of Fat Tissues

The following are the procedures used to make phantom fat:

- Making phantom starts from mixing refined magnesium oxide with calcium carbonate into a beaker glass containing distilled water, stirring gently, then mixing with sodium chloride to control the conductivity in the beaker glass.
- Beaker glass is heated and will be stopped when boiling symptoms appear evidenced by the presence of small bubbles.
- Mix the agar ingredients to increase viscosity through the sieve in the liquid little by little, and stir carefully, then mix Polyethylene into the liquid little by little, and stir carefully because of the agar-based mixing of the ingredients.
- Pour liquid into the mold. Phantom is cooled about one night at room temperature.
- Phantom taken from the mold after hardening.
- Cut phantom with different thickness of 2.5 and 8 cm

X-ray exposure on standard Phantom and Fat Tissue Phantom

The standard phantom is used to determine the reference value. Standard phantom testing process through irradiation using digital radiography aircraft with variations of 90 - 117 KV and 125 & 200 mAs and at a distance of 150 cm. data retrieval 3 times and repeated with a lag time every 2 hours. The quantity of radiation is the amount that states the amount of radiation intensity, parameters kV, mAs and distance produce the value of radiation intensity. The intensity before passing through the network (I0) is different from the intensity after passing through the network (I). This is caused by photons that affect the atomic electron of biological tissue, so interactions can occur such as absorption, scattering (deflection), or transmission. The intensity of the radiation can be measured using a digital survey meter.

Intensity value before and after passing the standard phantom material is used as a reference, then added fat tissue phantom with different thickne The ss to the standard phantom to find out the intensity value after passing through the two phantoms, from this intensity measurement will get the correction factor value.

(a) (b)

Figure 1: (a) artificial fatty tissue phantom (b) standard phantom

Measurement results

The process of taking phantom data is done by giving irradiation using 5 variations namely 90 kv, 96 kv, 102 kv, 109 kv and 117 kv and 2 variations of ma ie 125 and 200 with the same distance of 150 cm, the process of taking data is carried out as much as 3 times and repeats with a time lag every 2 hours.

For example the H2O water molecule formula, consisting of H and O atoms, with the number of moles of 2 moles of hydrogen atoms and 1 mole of oxygen atoms. Likewise for the Glucose compound with the molecular formula C6H12O6 consisting of C, H and O atoms, with a mole composition of 6 moles of C atom, 12 moles of H atom and 6 moles of O atom.

Table 1: Composition of each component

Component	Chemical formula	C	H	O	Mg	Ca	Na	Cl
(Atomic mass)		12	1	16	24	40	23	35,5
Aquades	H2O	0	2	1	0	0	0	0
PE	C2H4n	180	360	0	0	0	0	0
MgO	MgO	0	0	1	1	0	0	0
CaCO3	CaCO3	1	0	3	0	1	0	0
Agar	C14H24O9	12	18	9	0	0	0	0
NaCl	NaCl	0	0	0	0	0	1	1
Total number	591	193	380	14	1	1	1	1
Percentage of each Component		32,66%	64,30%	2,37%	0,17%	0,17%	0,17%	0,17%

The intensity of X-ray Radiation on the Standard Phantom

In the digital X-ray setting 125 mAs the intensity of radiation on phantom fat tissue with a thickness of 2 cm obtained values between 0.76 - 1.29, at a thickness of 5 cm ranging from 0.44 to 0.74 there was a decrease in intensity with an average of 0.43, while at an thickness of 8 cm ranging between 0.25 - 0.42 there is a decrease in intensity with an average of 0.67 to the fat tissue phantom thickness of 2 cm.

In the digital X-ray setting of 200 mAs the intensity of radiation on phantom fat tissue with a thickness of 2 cm obtained values between 1.22 - 2.07, at a thickness of 5 cm ranging from 0.71 to 1.19 there was a decrease in intensity with an average of 0.69, whereas at an thickness of 8 cm it ranged between 0.41 - 0.68 there is a decrease in intensity with an average of 1.09 to the fat tissue phantom thickness of 2 cm.

Measurement of fat tissue phantom intensity is influenced by kV and mAs values, the greater the mAs value, the higher the intensity produced. Likewise when irradiation is blocked by phantom fat tissue with a different thickness, at each increase in the kV value the intensity value also increases, it can be concluded that the intensity value is influenced by the kV value. Figure 4.3 shows the correlation between standard phantom intensity and fat tissue phantom with different thickness.

3. Result and Discussion

At 90 kV irradiation the initial intensity shows a value of 45 after passing through the irradiation object, the intensity will decrease due to absorption and scattering values between 0.25 - 1.83 with the lowest intensity value in fat tissue phantom of 8 cm thickness. on 117 kV irradiation the initial intensity shows the value 76 after passing through the irradiation object, the intensity will decrease due to absorption and scattering values between 0.42 - 3.09 with the lowest intensity value in fat tissue phantom of 8 cm thickness.

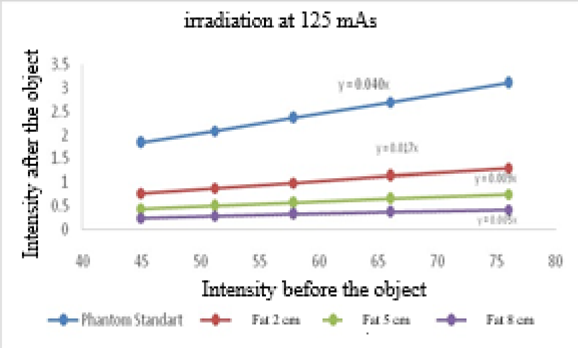

Figure 2: Correlation of Radiant Phantom and Standard Phantom Intensity Radiation Intensity Rate to Increase of kV at 125 mAs

The initial intensity of the irradiation of 90 kV has an intensity value of 6 this means the intensity value is greater than the measurement at 125 mAs. If the intensity value has decreased the same as 125 mAs, it can be seen in Figure 4.6 that at each increase in the kV value the intensity value has also increased, it can be concluded that the intensity value is influenced by the kV value. Figure 2 shows the correlation between standard phantom intensity and fat tissue phantom with different thicknesses.

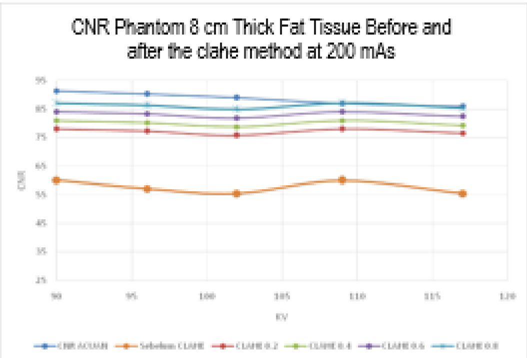

Figure 3: Comparison of CNR Value of Fat Tissue Phantom Tests against Standard Phantom thickness of 8 cm Before and After the CLAHE Method at 200 mAs

The addition of fat tissue phantom with a thickness of 8 cm to the standard phantom causes a decrease in image quality as seen from the CNR value The results of the CLAHE method test on the fat tissue phantom with a thickness of 8 cm obtained the smallest error value with CLAHE α = 0.8 is 2.51.

Table 2: Error Values for CNR Phantom of Fat Tissue against Standard Phantom with a thickness of 8 cm

Time flow (mAs)	CLAHE	Mean CNR after the CLAHE method Fat Phantom Thickness 8 cm	Error
Phantom Standart = 74.05			
125	α = 0.2	69.194	4.8562
	α = 0.4	70.94125	3.108748
	α = 0.6	72.68805	1.361948
	α = 0.8	74.43303	-0.38303
Phantom Standart = 88.04			
200	α = 0.2	77.054	11.582
	α = 0.4	80.035	8.605094
	α = 0.6	83.08171	5.558294
	α = 0.8	86.12851	2.511494

The CLAHE method with the α parameter is used to increase the CNR value, in Table 4.14 shows the error value for the thickness of the fat tissue phantom 8 cm against the standard phantom in the 125 mAs experiment obtained the smallest error value with CLAHE α = 0.6 is 1.36 while in the 200 mAs measurement value CNR Phantom of fat tissue against standard phantom before the CLAHE method obtained a large error value, after the CLAHE method the error value at 125 mAs with α = 0.4

4. Conclusion

The results of research conducted as:

- From this research , the result of correction factor of fat tissue phantom to standard phantom at 125 mAs is 1,402 for thickness 2 cm, 1,832 for thickness 5 cm and 2,079 for thickness 8 cm, at 200 mAs for 2,243 for thickness 2cm, 2,932 for thickness 5 cm and 3,328 at a thickness of 8 cm.
- The CLAHE method is used to improve image quality by changing the α parameter to increase the CNR value in fat tissue phantom to improve the CNR value of the standard phantom. Standard phantom CNR values at 125 mAs range between 66-81 and at 200 mAs range between 86-91. Standard phantom CNR values with the addition of Fat tissue phantom before the CLAHE method at 125 mAs with a thickness of 2 cm ranged from 43-58, a thickness of 5 cm ranged between 34-45 and a thickness of 8 cm ranged from 34-41 while at 200 mAs with a thickness of 2 cm ranges from 62-68, thickness of 5 cm ranges between 54-61 and thickness of 8 cm ranges between 55-60.
- CNR phantom standard with the addition of Fat tissue phantom after CLAHE method at s α = 0.4 with a thickness of 2 cm ranging from 72-75, α = 0.6 thickness of 5 cm ranging between 71-74 and α = 0.6 thickness of 8 cm ranging from 71- 73 whereas at 200 mAs α = 0.8 with a thickness of 2 cm, the range is 87-89, a thickness of 5 cm is between 85-87 and a thickness of 8 cm is between 84-87.
- Measurement of CNR Phantom value of fat tissue against standard phantom before the CLAHE method obtained a large error value, After the Clahe method the error value at 125 mAs with α = 0.4 at 2 cm thickness was 0.94, α = 0.6 at 5 cm thickness at 0.86 and α = 0.6 at a thickness of 8 cm at 1.3 while at 200 mAs with α = 0.8 at a thickness of 2 cm at 0.48, at a thickness of 5 cm at 2.35 and at a thickness of 8 cm at 2.5

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