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Effect of Contrast Enhancement on Radiographic Image Quality of TOR-CDR Phantom Object

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ABSTRACT

The test object was selected in the form of a *TOR-CDR phantom* which was exposed to X-rays with a low tube voltage (kV) and adjusted the contrast enhancement in the radiographic image. The study of this method was carried out by varying the tube voltage (kV) from 60 kV-80 kV and increasing contrast from 5%-30%. Based on the tests carried out, increasing the tube voltage (kV) can improve image quality, but increase the radiation dose received. However, giving *enhancement* can reduce tube voltage (kV) and improve image quality. The decrease in the average pixel value against the contrast on the TOR-CDR *phantom* follows the second order of polynomial equations, $y=Ax^2+Bx+C$. The coefficient A, B and C has linear relationship with the tube voltage (kV). The coefficient A has a decreasing trend and the coefficient B has an increasing tendency as the tube voltage (kV) increase. Meanwhile, the coefficient C shows the noise level in the image. Contrast enhancement can reduce the tube voltage (kV) used, but this contrast increase can only be done in a limited way. In this research, the maximum contrast enhancement limit in the image is 10% with 12-13 visible circles from 17 circles on the object.

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INTRODUCTION

X-rays are electromagnetic waves with wavelengths ranging from 10 nm - 100 pm. This wavelength includes short waves so that X-rays able to penetrate a material in its path (Quinn & Sigl, 1980). X-rays have great penetrating power of materials, but after penetrating a material, the intensity of X-rays weakens. The magnitude of the attenuation of the X-ray intensity is determined by the object's absorption coefficient (*μ)* to X-rays (Zelvani, 2017). Radiography is a field that used X-rays as ionizing radiation to form an image of an object then studied on film. Radiography has developed where analogue radiography is turned into digital radiography. In digital radiography, digital X-ray sensors are used instead of radiographic film and the film washing process is replaced by a computer system (Muttaqin & Susilo, 2017).

The quality of the radiographic image can be determined by the tube voltage (kV) (Sparzinanda et al., 2017). This is because the higher tube voltage, the stronger energy of the electrons in the tube from the cathode to the anode. The stronger electron energy causes X-rays to penetrate objects. In addition, the stronger electron energy, the result of radiographic image can be brighter (Wiguna & Fardela, 2015). Therefore, the higher kV, image quality will be better. However, the higher the kV, the higher the radiation dose (Hermann, 2008). This radiation dose arises as a result of radiation exposure. Increasing the radiation dose will have a negative impact on the health of the body so that it is necessary to reduce the radiation dose (Busch & Faulkner, 2005).

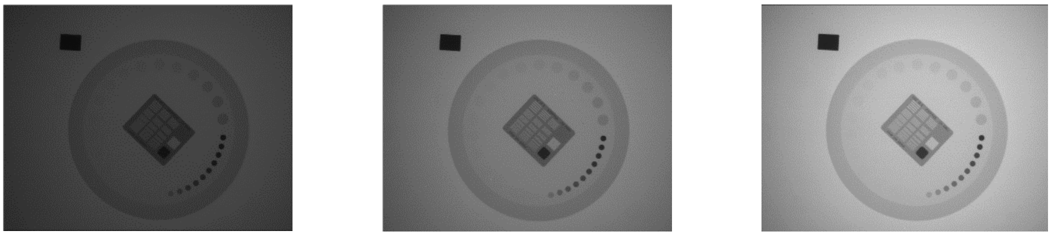
METHODS

This radiographic image was taken using a Digital Fluorescent X-Ray Radiography (RSFD), where the tube voltage exposure factor (kV) was varied from 60 kV-80 kV with 5 kV intervals, while the filament current (mA) and irradiation time (s) were fixed. The radiographic image was corrected using *Flat Field Correction* (FFC). The corrected image is then given variations in contrast enhancement using *software* and the average pixel value is analysed using *macros*. Contrast variation given is 5%-30% with 5% interval. Automatically, the average pixel value in the image will be written into Microsoft Excel. The average pixel value in the radiographic image can be processed and presented in the form of a graph of the relationship between the average pixel value and the contrast value contained in *the TOR-CDR Phantom* (Seeram, 2019).

This graph of the relationship between the average pixel value and contrast will show a comparison of the results for each kV tube voltage variation that is carried out. In this graph, *trendline* following the order of 2nd order polynomial pattern and the equation is obtained. The second-order polynomial equation has coefficient values A, B, and C. The coefficient values obtained are searched for linear relationships for each kV that has been done. Based on the graph of the relationship between each coefficient value with kV, it can be obtained the gradient value based on the equation of the *trendline* graph and calculations using the linear regression method.

RESULTS AND DISCUSSION

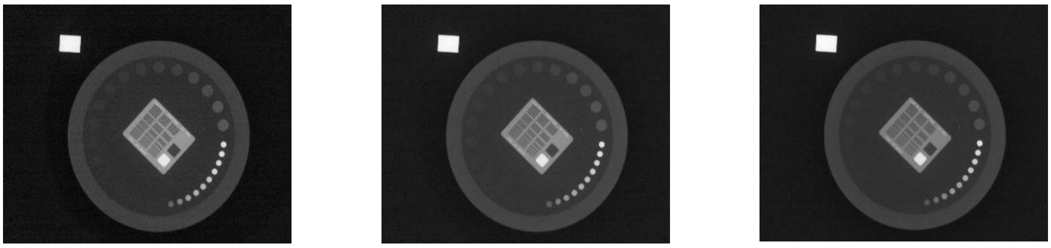
The radiographic image obtained from the exposure process can be shown in Figure 1. The radiographic image is then corrected using *Flat Field Correction* (FFC) with a *dark* image and *again* image. *Dark* and *gain* were taken before the exposure process for each variation of tube voltage (kV). The corrected image is shown in Figure 2. Based on the radiographic image, the image in Figure 2 can be seen clearly compared to the image in Figure 1.



(a) (b) (c)

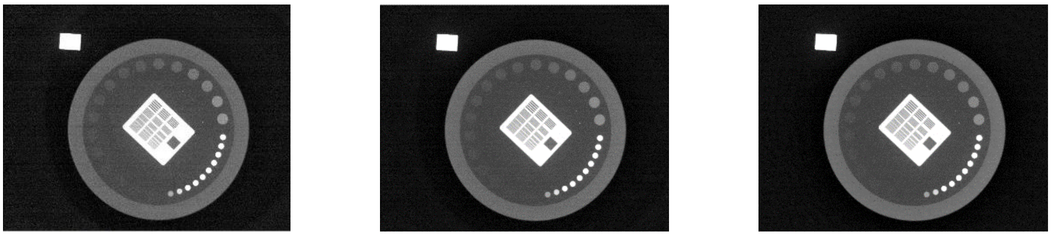
Figure 1. The radiographic image with variations in tube voltage (kV) at a value of (a) 60 kV; (b) 70 kV; (c) 80 kV

The sharpness of the image can be seen from the number of large circles visible on the object, where the number of large circles on the object is 17 circles. In the radiographic image with a tube voltage of 60 kV and 65 kV, 5 circles can be seen. At a tube voltage of 70 kV and 75 kV there are 6 visible circles. Meanwhile, at a tube voltage of 80 kV, 7 circles can be seen. In the FFC corrected image, 10 circles can be seen at 60 kV and 65 kV tube voltages. At a tube voltage of 70 kV, 75 kV, and 80 kV 11 circles are visible. Based on Figure 3, it can be seen 11 circles in the image with tube voltages of 60 kV, 65 kV, and 70 kV. Meanwhile, at a tube voltage of 75 kV and 80 kV, 12 circles can be seen.



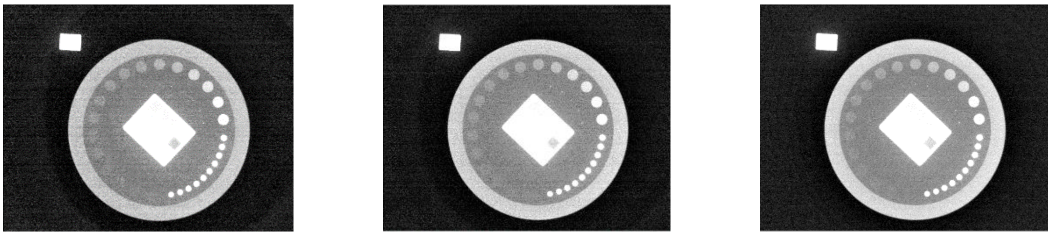
(a) (b) (c)

Figure 2. Corrected image with variations in tube voltage (kV) at a value of (a) 60 kV; (b) 70 kV; (c) 80 kV



(a) (b) (c)

Figure 3. Contrast enhancement variation image 5% with variations in tube voltage (kV) at a value of (a) 60 kV; (b) 70 kV; (c) 80 kV

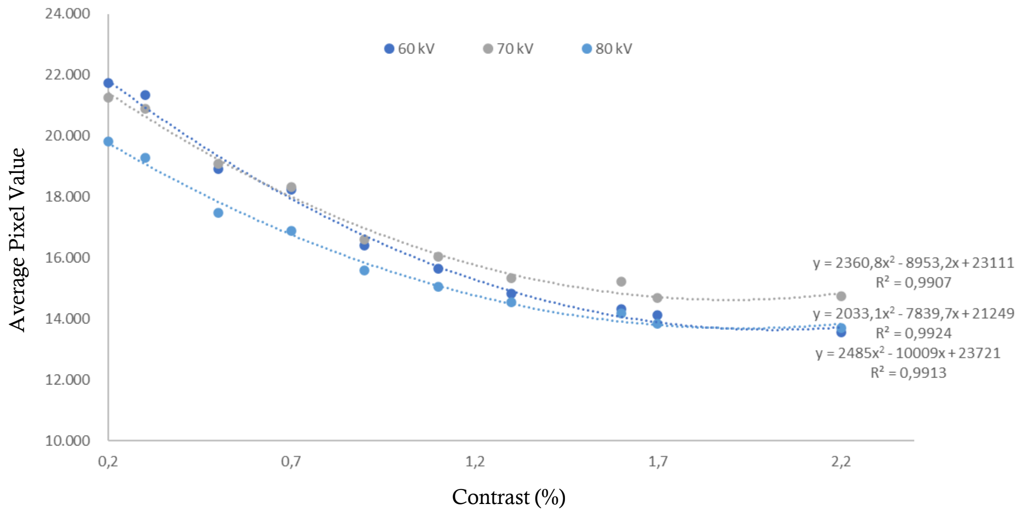


(a) (b) (c)

Figure 4. Image of variations in contrast enhancement 10% with tube voltage variation (kV) at a value of (a) 60 kV; (b) 65 kV; (c) 70 kV; (d) 75 kV; (e) 80 kV

Based on Figure 4, it shows that there are 12 circles at a tube voltage of 60 kV, 65 kV, 70 kV, and 75 kV, and 13 circles at a tube voltage of 80 kV. The corrected image given a 15% contrast increase variation can be seen 13 circles in the image of all the tube tension variations carried out. In the corrected image given a 20% contrast increase variation, 14 circles can be seen in the image of all variations of the tube voltage performed. Corrected image with variations in contrast enhancement 25% there are 15 circles that can be seen. Meanwhile, in the corrected image given a 30% contrast increase, 16 circles from 17 circles on the TOR-CDR *Phantom* can be seen (Hendee & Ritenour, 2002). This indicates that the administration of contrast enhancement on the radiographic image can improve image quality (Gonzalez & Woods, 2008).

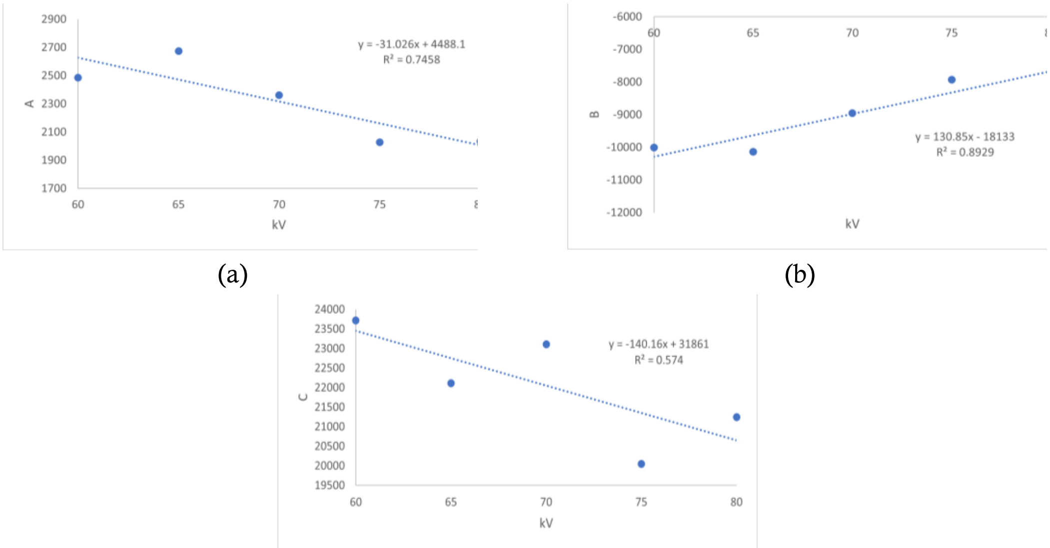
The graph of the relationship between the average pixel value and the contrast on the TOR-CDR *phantom* shows the change in the average pixel value of the image as a function of contrast variations on the object where the average pixel value will decrease as the contrast increases. The decrease in the average pixel value with increasing contrast follows the form of a polynomial of order 2 according to Beer Lambert's Law where the intensity is proportional to V^2I (Bushong, 2013).



Graph 1. Graph of the relationship of the average pixel value and contrast with various variations in tube voltage (kV) on high-low contrast FFC corrected images

Based on the second order polynomial equation, the coefficient values of A, B, and C can be found which can be searched for their linear relationship with the variation of kV. The value of coefficient A has a tendency to decrease and the value of coefficient B increases when kV increases.

The graph of the relationship between the coefficients of C and kV shows that the data fluctuates and there is a linearity deviation. Therefore, the value of the coefficient C is defined as *noise*.



(a) (b)

(c)

Graph 2. Linear graph of the relationship between the value of the coefficient and the variation of tube voltage (kV). (a) coefficient A; (b) coefficient B; (c) coefficient C

Contrast-enhanced image 10% is the maximum contrast enhancement. This is due to the irregularity of the coefficient values obtained in the image resulting from the increase in contrast above 10%. There is a linearity deviation in the contrast-enhanced image 15%, where the data obtained is not stable. This results in an information that in some cases, contrast administration cannot be given 100% (Sartinah et al., 2008).

The radiation dose will increase in proportion to the increase in kV which will also be proportional to the increase in the quality of the radiographic image (Fahmi et al., 2008). However, an increase in contrast can reduce kV and improve image quality. Therefore, the quadratic value of the second-order polynomial equation obtained will decrease and is proportional to the decrease in dose (Roberts & Williams, 2008).

CONCLUSION

The increase in kV variation is proportional to the increase in the quality of the radiographic image and the increase in the radiation dose profile. Changes in kV cause a tendency to decrease the coefficient A & increase the coefficient B of the second-order polynomial equation, the relationship between decreasing the average pixel value and increasing the contrast of the object. Giving an increase in contrast to the radiographic image can reduce kV, but the quality of the radiographic image increases. The quadratic value of the second-order polynomial equation will decrease whose value is proportional to the decrease in the radiation dose.

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