International Journal of Innovative Research in Advanced Engineering (IJIRAE) ISSN: 2349-2163
Issue 03, Volume 6 (March 2019) www.ijirae.com

EFFECT OF SILICON - RUBBER (SR) SHEETS AS AN ALTERNATIVE FILTER ON HIGH AND LOW CONTRAST OF THE TOR CDR PHANTOM

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Manuscript History - Number: **IJIRAE/RS/Vol.06/Issue03/MRAE10082**
Received: 03, March 2019
Final Correction: 14, March 2019
Final Accepted: 24, March 2019
Published: **March 2019**
Citation: Susanto, HeriSutanto, EkoHidayanto, ChoirulAnam, Arifin, Z., Jaya, G. W., Daryati, S. & Indrayani, U. (2019). Effect of Silicon Rubber (SR) Sheets as an Alternative Filter on high and low Contrast of the TDR Phantom. IJIRAE::International Journal of Innovative Research in Advanced Engineering, Volume VI, 267-272.
doi://10.26562/IJIRAE.2019.MRAE10082
Editor: Dr.A.Arul L.S, Chief Editor, IJIRAE, AM Publications, India

Abstract–A digital radiography delivers a radiation dose to patients; therefore it poses potential risk to the patients. One effort to reduce dose is carried out using a radiation filter, e.g. Silicone Rubber (SR) sheet. The purpose of this research was to determine the impact of the SR sheet on the high contrast objects (HCO) and the low contrast objects (LCO). The dose reduction was determined from attenuation x-rays before and after using the SR sheet. Assessment of HCO and LCO was observed from CDR TOR phantom at tube voltage of 48 kVp and tube current of 8 mAs. The physical parameter to assess image quality was the Signal to Noise Ratio (SNR) value in LCO. The maximum x-ray attenuation using the SR sheet is 48.82%. The visibility of the HCO remains the same, namely 16 objects; however the LCO slighly decreases from 14 objects to 13 objects after using the SR sheet. The SNR value decreases with an average value of 15.17%.Therefore, the SR sheet as a alternative filter has no effect on the HCO and has realtively little effect on the LCO. Thus, the SR sheet potentially is used for radiation protection in patients, especially on examinations that do not require low contrast resolution.

Keyword: High contrast object, Low contrast object, Digital radiografi, and Silicone Rubber (SR) sheet.

I. INTRODUCTION

Radiography is an imaging modality using X-rays for its image acquisition. The X-rays are high energy electromagnetic waves that are strong enough to penetrate certain materials. In humans, the anatomical organs have different density characteristics according to their constituent material.

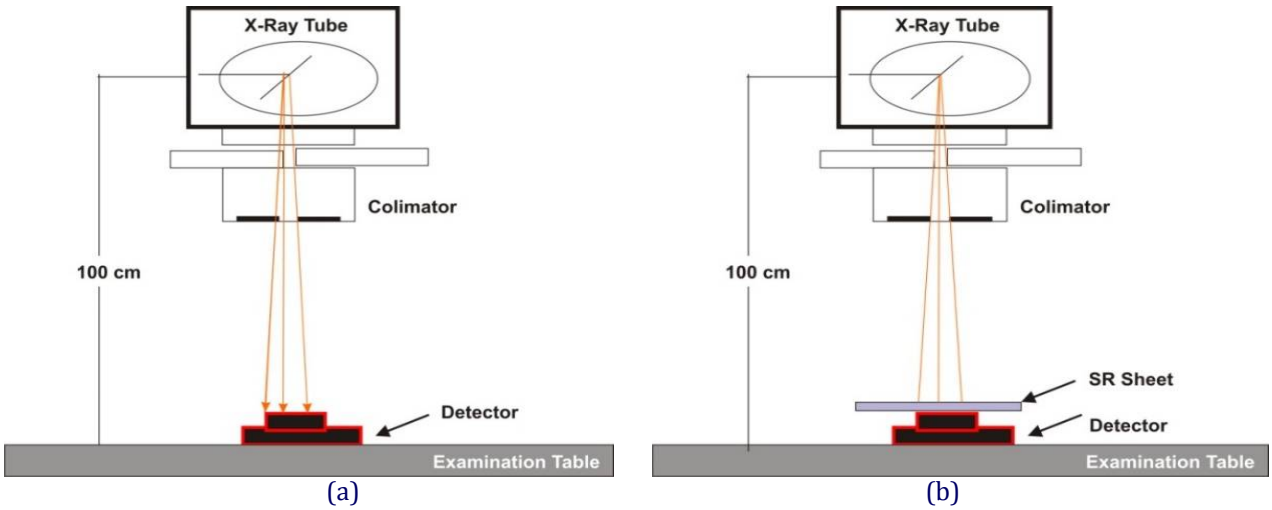
When X-rays penetrate the patient's body, some of the radiation will be absorbed and it will produce different grey levels on the image recorder [1]. The difference in grey level will result in a diagnostic image contrast value. A solid tissue will produce high contrast (white) while soft tissue will produce low contrast (black) [2]. In the chest area, there are many type of tissues, for example the mediastinum which has high contrast and the lungs for low contrast [3]. To obtain diagnostic information, the resulting image must be able to distinguish between one organ and its surrounding, and this is referred to as a contrast resolution. The contrast of some tissues may not appear clearly, for example soft tissue and muscle, because they have almost the same attenuation. For high contrast organs, for example, bone and soft tissue will look very contrast [4-6]. Initially,a film was used as an image receptor, and it is called as Film Screen Radiography (FSR). In the 1980s, Computed radiography (CR) and Digital Radiography (DR) were introduced. Both of them quickly replaced the FSR as an image recorder because it has many advantages over the FSR. The advantages of digital radiography are it has a wide dynamic range, faster response; the image can be manipulated after acquisition, no need for repetition due to over- and under-exposed, and can be stored as electronic digital data [7-9].

The transfer of technology from FSR to DR does not mean reducing doses. Repetition of image acquisition because over-exposed or under-exposed can indeed be avoided, however it creates new potential problems. For example, to obtain quality images, the radiographers tend to increase the exposure factors. The high exposure parameters are sometime no longer useful, because the diagnosis can be determined using low exposure. Hence, it should be noted that the use of digital radiographs tends to increase doses [8-11]. Anticipation of increasing doses in the use of digital radiography needs to be done. The concept of “as low as reasonable achievable (ALARA)” must be implemented. Optimization of the use of DR to achieve the quality image with lowest possible dose must be sought. X-ray imaging helps clinical diagnosis more accurately, on the other hand the absorption of radiation in the body has the potential to become cancerous. The resulting image should meet the required standards. Thus radiation safety will be achieved [1,9,12]. One method to optimize the radiation dose is to use a radiation filter. The radiation filter is generally made of Aluminium (Al) and Copper (Cu). Recently, silicone rubber (SR) is used in the medical field because it is elastic and flexible [13]. This material is inside the blanket clothing and curtains for radiation protection purposes [14]. Previously, the SR material has been proposed as an alternative radiation filter. To date, impact of the SR on low and high contras objects has not been evaluated. In this paper, we evaluate the effects of SRs as a filter on the high contrast object (HCO) and the low contrast object (LCO) of CDR TOR phantom.

II. METHOD

A.X-RAY ATTENUATION

X-ray attenuation on silicone rubber (SR) sheet was tested on the mobile radiography system (Polymobil Plus Siemens, Sweden) at Training Center (TC) of Diponegoro University. The exposure factor was set at tube voltage of 48, 60, 70, 81, 90, and 101 kVps.Tube currents and irradiation times of 8 mAs at a distance of 100 cm. The schematic diagram of the study is shown in Figure 1.



(a) (b)

Figure 1. The scheme of x-ray attenuation measurement (a) without SR and (b)with SR

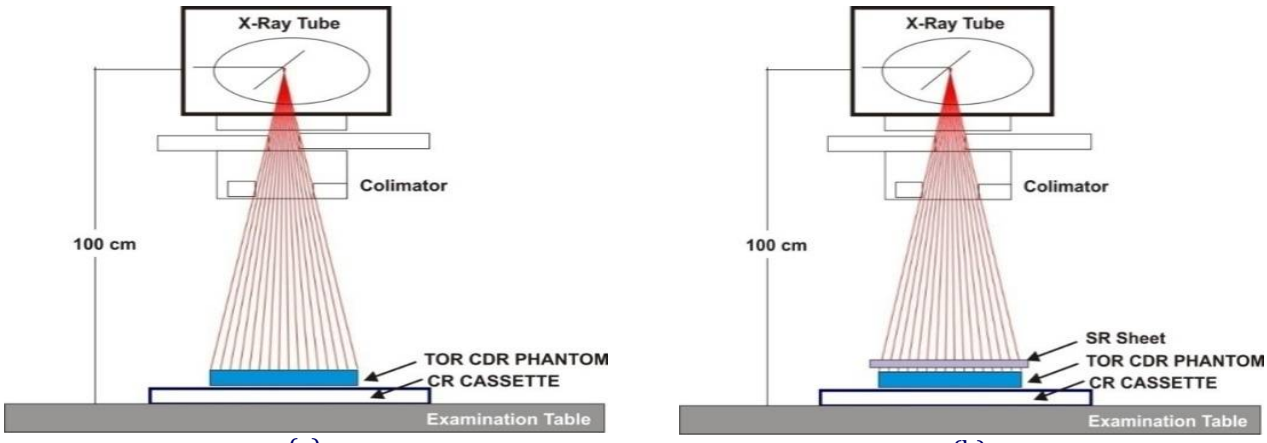
The initial dose was obtained from irradiation directly on the detector without the SR [15]. Next, the SR was located above the detector and dose measurement was carried out. The value of x-ray attenuation was calculated using the equation:

$$X_{AP} = \frac{I_0 - I}{I_0} x100\% \quad \text{Eq.1}$$

With X_{AP} is X-ray attenuation percentage, I is the dose of X-ray after passing through the SR material (mGy), and$I_0$is the dose of X-ray radiation directly hits the detector without any SR object (mGy) [16].

B. Image acquisition

The images of CDR TOR phantom with and without SR sheet was obtained using the general radiography unit (Shimadzu). A computed rradiography (CR) unit (Fuji, Japan) with a cassette size of 35 cm x 35 cm was used to record the images. The exposure factor was set at a voltage of 48 kVp and a current-time of 8 mAs which is a standard exposure factor on limb examination. The schematic diagram of the CDR imaging with and without SR sheet can be seen in Figure 2.

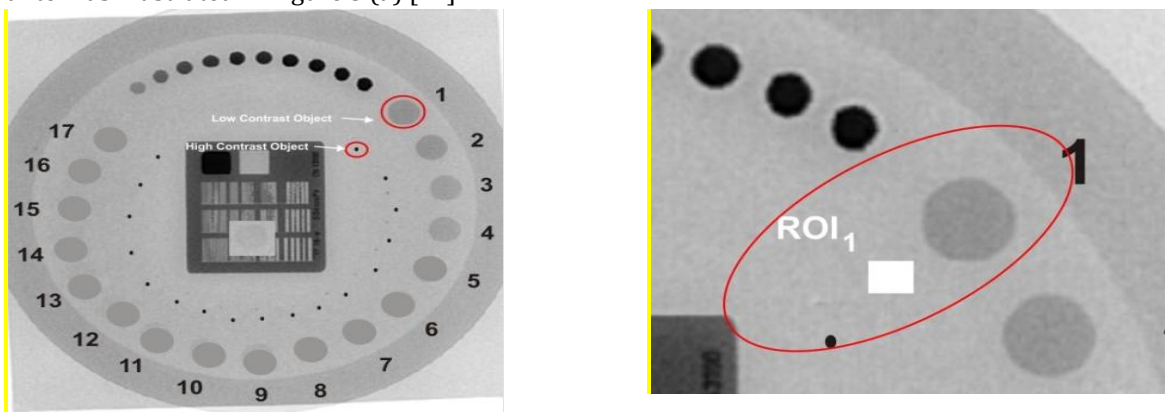


(a) (b)

Figure 2. The scheme of image acquisitions (a) TOR CDR onlyand (b) with SR sheet

C. Visibility of TOR CDR phantom

The TOR CDR phantom is made of perspex in the form of discs with a diameter of 18 cm and 1 cm thick. Inside the phantom, there are the high contrast objects (HCO) and the low contrast objects (LCO) each with a diameter of 0.5 mm and 11 mm, respectively. The number of each HCO and LCO are 17 pieces arranged in a circle on the edge of the phantom as illustrated in Figure 3 (a) [17].



(a) (b)

Figure 3. The image of (a) TOR CDR phantom and (b) aROI in the phantom

Image quality before and after use of the SR sheet was observed from the number of visible objects. The image quality decreases if the number of visible circles decreases.

D.Signal to noise ratio (SNR)

Signal to noise ratio (SNR) is one metric to measure radiographic image quality [18]. The SNR value for specified regions of interest (ROI) was calculated using the following equation:

$$SNR = \frac{ROI_1}{SDROI_1} \quad \text{Eq.2}$$

ROI_1 is the average value of pixel values of the object, $SDROI_1$ is the standard deviation of the background [19]. The ROI for HCO and LCO measurement is shown in Figure 3b. The signal is defined as the average pixel intensity in the LCO in the ROI of the CDR TOR phantom. Noise is defined as a random variation of pixel values in an area outside the object.

Standard deviation (SD) of the noise was calculated from pixels located in the background of the image, namely the area around LCO. SNR was calculated by dividing the average signal by the standard deviation from noise [19-21]. All results obtained were analyzed by comparing parameters before and after using the SR sheet. MATLAB 2015a (Mathwork, Inc., USA) was used for image analysis to assess SNR and visibility of LCO.

III. RESULT AND DISCUSSION

A. X-ray attenuation

The X-ray attenuationsof the SR sheets with 0.6 cm thickness at tube voltage variation are shown in Figure 4. The percentage of X-ray attenuation in the SR sheet ranges from 29.71 - 48.82%. An increase of tube voltage causes an increase in energy of X-ray beam so that the penetrating power increases, as a result the attenuation percentage (X_{AP}) decreases. Figure 4 shows that the highest percentage value is at 48 kVp and the lowest value is at 101 kVp.

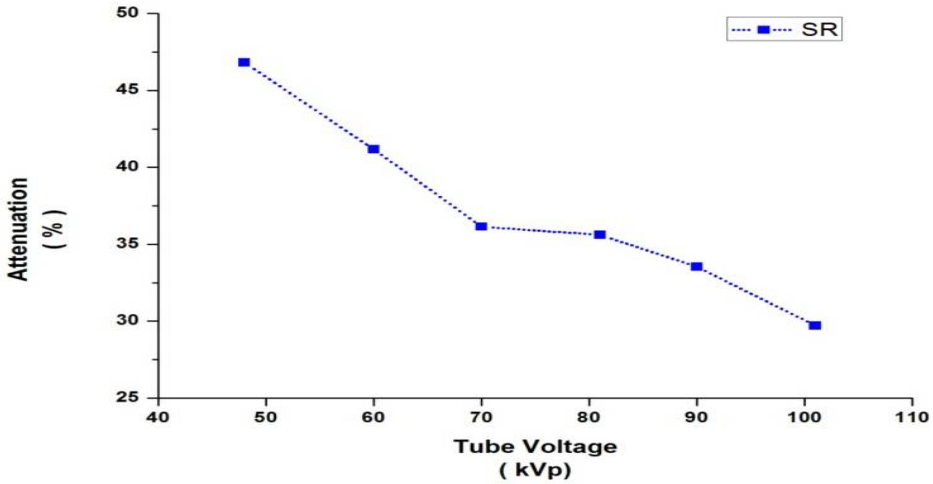


Figure 4.Percentage of X-ray attenuation on SR sheet for tube voltage variation

B. SNR

Diagnostic images can be accepted if the image provides clinical informations. For this reason, it is necessary to enhace the signals received by the image recorder. The increase of the signal to noise ratio, the better image quality will be obtained, but the dose received by patients will also increase. The use of the SR sheet decreases the SNR value because it absorbs the intensity of the signal received by the image receptor. The absorbtion of this signal aims to reduce the radiation dose, but it is expected that the imageis still in quality to accurately diagnose patient abnormalities. The graph of the SNR value in the ROI area on the TOR CDR phantom can be seen in Figure 5 a.

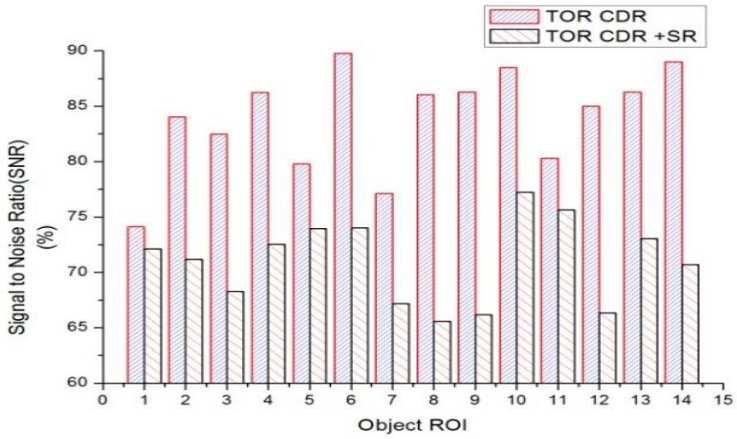


Figure 5. SNR value on TOR CDR phantom with and without the SR sheet

Based on Figure 5, the decreasing percentage of SNR varies from 4.63% (in the 8th object) to 28.38% (in the 10th object). The average percentage reduction from the whole measurements is 15.17%. Based on Figure 6, the decreasing percentage of SNR varies from 4.63% (the lowest) in the measurement of 8th ROI to 28.38% (the highest) in the measurement of 10th ROI. The average percentage reduction from the whole measurement is 15.17%. In a previous study, it was reported that a decrease in SNR of 36% from the original image did not significantly reduce image quality [22]. Thus, the use of SR sheet hasa little impact on quality of the original image.

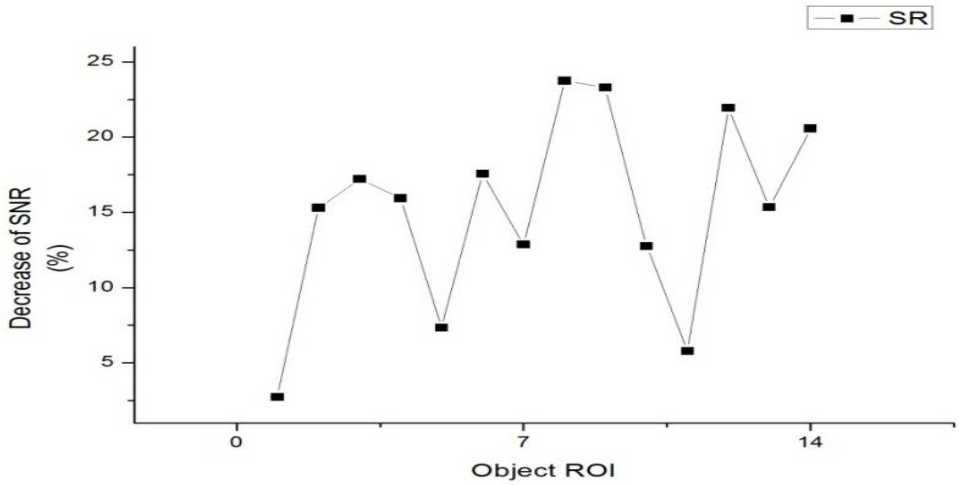
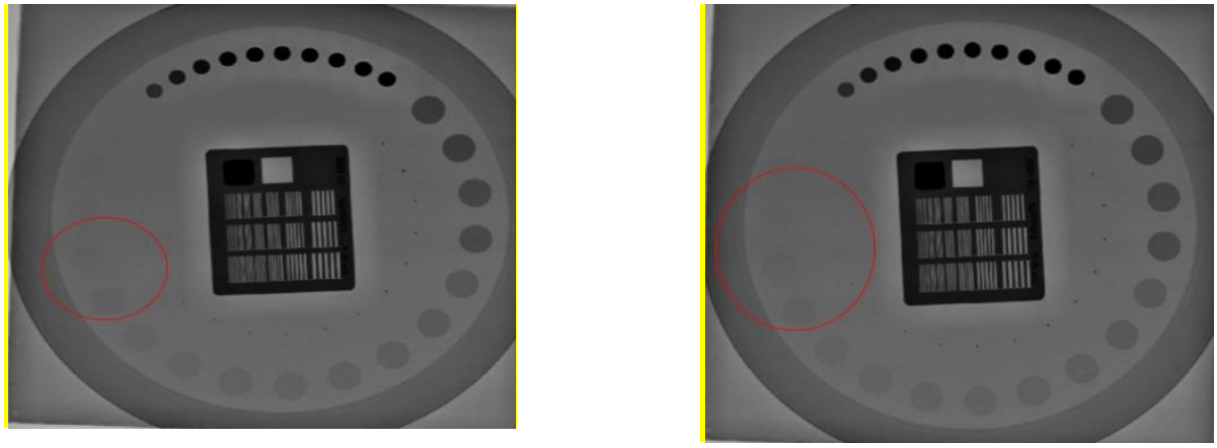


Figure 6. Percentage of decreasing SNR in the objects

C. Visibility

The image of the HCO and LCO of the CDR TOR phantom can be seen in Figure 7. This image was evaluated by visual observation at the number of circles can be seen before and after the use of the SR sheet. It can be seen that without SR sheet, 14 objects was visually observed, and with SR sheet, 13 objects was visually observed. Hence, the use of SR sheet slightly decreases the low contrast detectability. For hight contrast object (HCO), there are no different with and without the SR sheet, 16 objects are viasually observed with and without the SR sheet.



(a) (b)

Figure 7.Visibility of the TOR CDR phantom (a) without SR sheet and (b) with SR sheet.

IV. CONCLUSIONS

The SR sheet will absorb the radiation received to the patient. Reduction of radiation intensity will reduce image quality, in this case a decrease in SNR value. Reduction of radiation intensity by 48.82% will reduce the SNR by an average of 14.55%. Visually, the low contras detectability slightly decreases, from 14 objects observed without the SR sheet to become 13 objects after using the SR sheet. However, there is no effect on HCO, the number of HCO observed still the same,i.e. 16 objects. Thus, the SR sheet can be used as a tool of radiation filter for protection of radiological examination, especially for indications that only require a diagnosis of high-contrast organs, for example bone examination.

ACKNOWLEDGMENT

The authors acknowledge to the Ministry of Research and Technology of Indonesia, the Material Physics Laboratory, Department of Physics, Diponegoro University, Semarang. The authors also thank to the Training Center, Diponegoro University, Semarang, Regional Public Hospital Tugurejo, Semarang and the Health Polytechnic of the Ministry of Health, Semarang.

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