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European Journal of Advances in Engineering and Technology, 2019, 6(12):93-97

Research Article ISSN: 2394 - 658X

A Developed Silicone Rubber-Lead (SR-Pb) Shield as Gonad Shield during Lumbar Radiography

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ABSTRACT

Background: A silicon rubber-lead (SR-Pb) as an organ shield had been proposed. However, it was only used for the eyes shield in CT examination and it had single thickness. Therefore, it is necessary to develop various thicknesses and implement it to digital radiography (DR), such as lumbar examination. Objective*: To investigate the SR-Pb as a gonad shield to dose reduction and assess image quality produced during the lumbar examination.* Material and Method*: The sample was made from silicone rubber (SR) and lead (Pb) with various thicknesses. The SR-Pb was evaluated on an anthropomorphic phantom in lumbar examination by using the DR. The dose area product (DAP) was used to evaluate the dose reduction. While the exposure index (EI) and signal-to-noise ratio (SNR) were used to assess image quality.* Result*: This study was found that the SR-Pb with thickness of 1.0 cm reduces the dose area product and exposure index up to 30%. The use of SR-Pb as gonad shield causes the greater mean pixel and standard deviation of image. As consequence, signal-to-noise ratio decreases to 37%.* Conclusion*: The SR-Pb has ability to be used as a gonad shield, since it significantly reduces radiation and relatively maintains the image quality*.

Key words: SR-Pb, Gonad Shield, Image Quality, Dose Reduction, Radiography

INTRODUCTION

One of the efficient methods for protecting organs that are sensitive to radiation during radiographic examination is by the use an organ shield [1]. The gonad shield, for example, is used in the radiographic examination where the gonad receives primary radiation, however the gonad is not an organ of interest. The use of the existing gonad shield was reported to achieve a dose reduction up to 50%[2]. However, several studies suggested not to use the gonad shield. Because, the use of the gonad shield is often incorrectly positioned and it significantly reduces image quality [3–7]. Nowadays, the development of alternative gonad shield is carried out, such as bismuth and tungsten shields. Both of them have good performance to reduce the radiation. However, the bismuth shield still causes an increasing image noise up to 37% [8], and the tungsten shield is only effective at certain kVp, such as 60 kVp [9]. In addition, bismuth and tungsten sheets are not flexible materials [10], therefore their ability to cover abdomen surface for every patient is not perfect. Hence, it is needed to develop an alternative gonad shield that is significantly reduces the radiation dose but able to maintain the image quality from flexible materials.

A silicone rubber-lead (SR-Pb) as organ shield had been previously introduced. Irdawati et al [11] had synthesized the SR-Pb and implemented it as eye shield in CT examination. They reported that the synthesized SR-Pb was able to reduce dose up to 50%, without causing any significant artifact in the image. However, the previous study had only a thickness of 6 mm and used in eye protection [11]. Therefore, this study mainly sought to develop the SR-Pb with various thicknesses and implement it for other organs such as gonad in lumbar examination using the digital radiography (DR).

DESIGN, MATERIAL, PROCEDURE, TECHNIQUE OR METHODS

Sample Preparation and Dose Measurement

The SR-Pb as gonad shield was synthesized from the silicone rubber (RTV 52), Pb powder (Lead Acid), and other materials such as aquades, catalyst (Bluesil catalyst), and polyethylene glycol (Indrasari Chemical Store, Semarang, Indonesia). The concentration of Pb was 5 wt%. The novelty of this study was the various thicknesses of the SR-Pb, i.e. 0.2, 0.4, 0.6, 0.8 and 1.0 cm. The gonad shield dimension was 27 x 17 cm^2. The synthesis steps were shown in figure 1. The synthesis was begun by dissolving the PEG in aquades, then stirred at 60 degrees for an hour. The PEG solution was added with Pb and stirred again. Then the PEG-Pb solution was mixed with SR about 30 minutes and added catalyst, then mixed again about 6 minutes. Next step was pouring it into a mold that was smeared with silicone oil. The last synthesis step was cut the SR-Pb to resemble the shape of gonad shield.

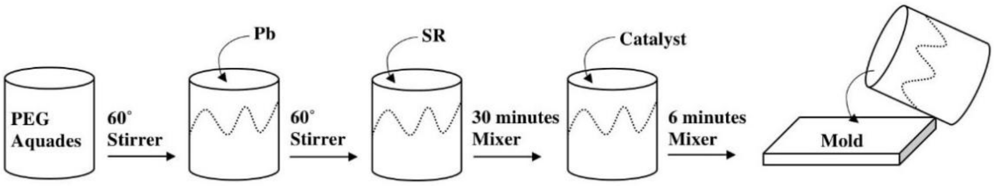

Fig. 1 The procedure of SR-Pb synthesis, the SR-Pb was made with the various thickness

The SR-Pb as gonad shields were implemented on an abdominal part of anthropomorphic PBU-50 phantom (Kyotokagaku co., Ltd., Japan) scanned by the Digitaldiagnost C50 Philips digital radiography. The dose area product (DAP) meter was integrated in the Digitaldiagnost C50 Philips digital radiography. The set-up parameters in this study were tabulated in Table 1, and set-up design was indicated by Fig. 2. In addition to using the DAP metric, this study also used the exposure index (EI) metric. The EI was defined as the amount of exposure to a specific area of image receptor [12–15]. The thickness of scanned object, collimation, grids, source-to-image distance, and image plate size influenced EI value. The EI in Philips DigitalDiagnost was defined as in equation (1) [12].

$$EI = \frac{1000}{K} \tag{1}$$

where K is the air kerma in μ Gy at the detector entrance[12].

Table -1 Set up experiment for dose measurement and image assessment

Equipment Model	Digitaldiagnost C50 Philips Digital Radiography
Examination	Lumbar
Projection	Anterior-Posterior (AP)
kVp	77
mAs	32
Collimator field	21 x 48 cm^2
SID	100 cm
AEC	No

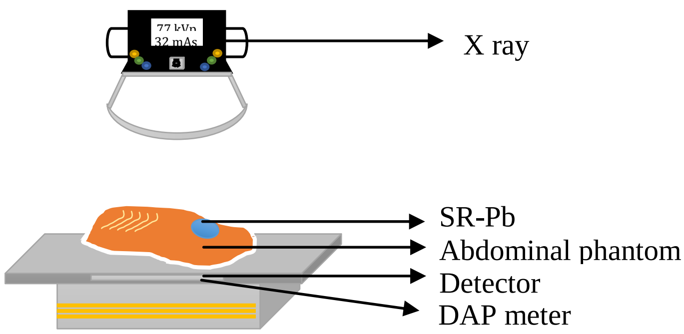

Fig. 2 The basic set-up of lumbar examination using the SR-Pb gonad shield for dose measurement and image quality assessment

Image quality assessment

Image quality assessment was indicated by the mean pixel value (PV) and the signal-to-noise ratio (SNR) values. The PV and SNR were measured from the images using the ImageJsoftware (National Institute of Health, Bethesda, MD). The six-circular region of interests (ROIs) were drawn on the lumbar image (Fig. 3). The ROIs were located at the left and right ovary regions. The SNR was calculated as comparison between PV and the standard deviation of the pixel value within the ROI [16].

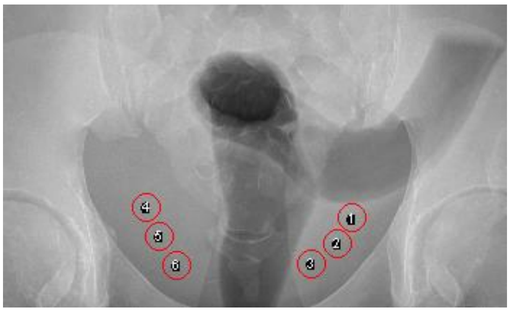

Fig. 3 The ROIs were placed at the right ovary (represented by ROI numbers of 1, 2, and 3) and left ovary (represented by ROI numbers of 4, 5, and 6) in images of the lumbar examination

RESULTS AND DISCUSSION

Radiation dose

Radiation dose is evaluated by dose area product (DAP). The radiation doses as function of the SR-Pb thickness are shown in Fig. 4. The use of SR-Pb as gonad shield leads to the decrease of DAP. The decreasing percentage of the DAP for SR-Pb thicknesses of 0.2, 0.4, 0.6, 0.8, 1.0 cm are 5.95, 11.90, 17.85, 23.80, and 29.75%, respectively (Fig. 4(a)). The EI decreases for all thicknesses of SR-Pb. The decreasing percentage of EI for SR-Pb thicknesses of 0.2, 0.4, 0.6, 0.8, 1.0 cm are 0.00, 6.34, 6.34, 9.66 and 11.78%, respectively. The function of linier regression is $y = -41{,}5714x + 332{,}9524$ with r^2 = 0.9314 (Fig. 4(b)).

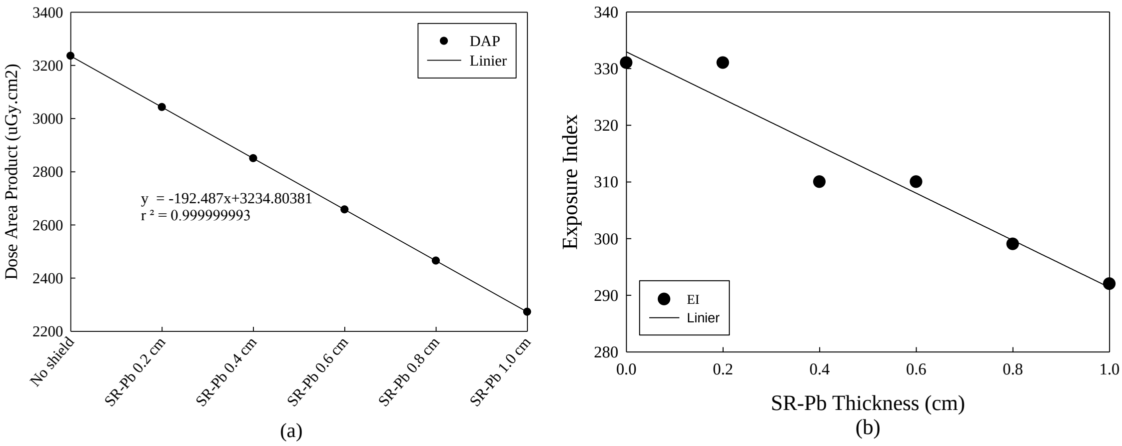

Fig. 4 (a) The dose area product (DAP) for SR-Pb with various thicknesses, and (b) the exposure index (EI) for SR-Pb with various thicknesses

Image Quality

The results of image quality assessment are shown in Fig 5 (a-b). The mean pixel (PV) and signal-to-noise ratio (SNR) of the ROIs are shown in Fig 5(a-b). It shows that PV and SNR increase with the increase of SR-Pb thickness.

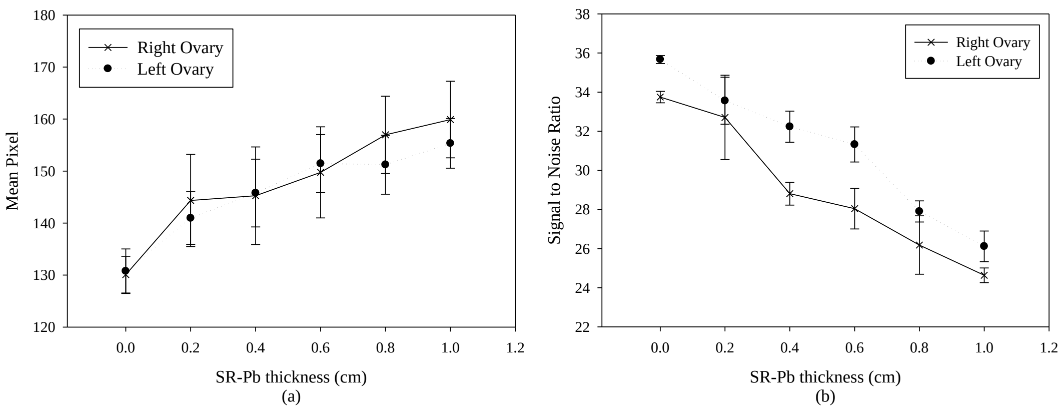

Fig. 5 (a) The mean pixel value (PV) for SR-Pb with various thicknesses, and (b) the signal-to-noise ratio (SNR) for SR-Pb with various thicknesses

The increasing percentage of PV by using all thicknesses of SR-Pb are 10.96-22.92% for right ovary and 7.80-18.79% for left ovary. In other hand, the decreasing percentage of the SNR are 6.82-36.56% for right ovary and 6.26-36.97% for left ovary.

The current study investigated the dose reduction and image quality assessment of SR-Pb as a gonad shield during the lumbar examination. The dose reduction evaluation used the metric of the DAP. The impact of thickness of the SR-Pb was also examined. As the result, this study found that SR-Pb has the ability to reduce the DAP up to 30% at the thickness of 1.0 cm. When the radiation passed the SR-Pb, it is absorbed by the SR-Pb. The radiation absorption increased with the increase of added Pb content along with the increasing of thickness.

The EI did not directly relate to the patient dose, however, it was related to image quality due to the amount of exposure at detectors. Nevertheless, the EI was used by operator for maintaining the signal value on the image. The high signal image was associated by the good image quality even though high patient dose [15]. This study shown that EI decreased with increasing thickness of SR-Pb (Fig. 4(b)). The EI decreasing reached up to 30%.

Figure 5(a) showed the mean pixel (PV) increase following the thickness of SR-Pb. The study has shown that the SR-Pb change the PV due to the SR-Pb change the x-ray effective energy [17]. The use of SR-Pb also cause the bigger noise value of the image. As the result, the SNR values for both ovaries decreased with the increase of the SR-Pb thickness (Fig. 5(b)).

This study examination is without Automatic Exposure Control (AEC). The limitation of this study is that the image quality was not assessed by radiologist. In addition, it is necessary to investigate the effect of SR-Pb on the entrance skin dose.

CONCLUSION

An alternative gonad shields based on the SR-Pb with various thickness are made. The ability of SR-Pb dose reduction increases along with the increase of SR-Pb thickness. The ability of the SR-Pb to reduce the DAP and EI are up to 30% at 1.0 cm. That means there is a decreasing exposure received by detector. The effect of the SR-Pb to image quality reveals that the SR-Pb for all thicknesses decrease the SNR. Therefore, the SR-Pb can be potentially used as an alternative gonad shield to reduce dose without deteriorating the image quality.

Acknowledgements

The authors wish to thank to the Ministry of Research, Technology and Higher Education of Republic of Indonesia and National Diponegoro Hospital for supporting this work.

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