International Journal of Scientific Research in Science and Technology
Available online at : www.ijsrst.com
Print ISSN: 2395-6011 | Online ISSN: 2395-602X
doi : https://doi.org/10.32628/IJSRST52310683

A Comparative Analysis between SR-Pb Shield and TCM in Eye Dose of Head CT Examination

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ARTICLEINFO

Article History:

Accepted: 10 Dec 2023
Published: 26 dec 2023

Publication Issue
Volume 10, Issue 6
November-December-2023

Page Number
408-413

ABSTRACT

This study aims to compare the effectivity of silicone rubber-lead (SR-Pb) eye shields and TCM technique during head CT examinations. In this study, a 95-5 wt% SR-Pb eye shield was developed with dimensions of 17 cm ×17 cm ×0.6 cm. This study was carried out at three tube voltages, namely 80, 100, and 120 kV. The measurements were conducted using Optically Stimulated Luminescence Dosimeter (OSLD) as the point dosimeter. Image noise and CT number were measured within specified region of interests (ROIs). These ROIs were positioned in three regions: the right eye, the left eye, and the central area of the head. Comparison of dose and noise was carried out in three conditions: without using SR-Pb and TCM (initial conditions), only using SR-Pb, and only using the TCM technique. From this study, it was found that the use of SR-Pb reduced eye dose as the use of TCM. It was found that a greater dose reduction was obtained when using SR-Pb compared to using TCM. Meanwhile, the use of SR-Pb led to slightly increasing noise and changing the CT number. In conclusion, the use of SR-Pb eye shield can serve as an alternative for eye dose reduction in CT machines that do not support TCM mode.

Keywords: Tube Current Modulation, OSLD, eye shield, silicone rubber, dose reduction

I. INTRODUCTION

The computed tomography (CT) scanner is a medical imaging technology that utilizes X-rays to produce detailed cross-sectional images of the body. Advances in CT development, particularly in improving image quality, are crucial for medical diagnosis. However, it is noteworthy that achieving an optimal image quality is often associated with delivering high radiation doses [1]. It is important to understand that the risks of radiation dose, especially to highly sensitive organs such as the eye lens in head CT examinations, should be optimized [2]. Tube current modulation (TCM) represents an important approach in CT for the optimization of radiation to produce high-quality images while minimizing unnecessary doses [3]. This technological innovation is a strategic element in CT development, emphasizing the need for balanced radiation dose and image quality. The inherent advantage of the TCM technique lies in its capability to adapt tube current to the specific requirements of each anatomical region, thereby preventing the wasteful of radiation doses. The effective implementation of radiation dose efficiency in the TCM technique involves conducting a topogram of the object (patient or phantom) and subsequently adjusting the tube current based on the body's size and contour. Notably, the tube current is increased in thicker body sections and reduced in thinner areas [4-6].

Another recommended optimization technique involves employing shields crafted from silicone rubber (SR) mixed with materials that possess radiation-attenuating capabilities, such as lead (Pb), bismuth (Bi), barium (Ba), and various other substances [7-9]. The efficacy of the SR-Pb shield was previously investigated for shielding the breast in thoracic CT examinations, achieving a notable reduction in doses down to 38%, while concurrently maintaining a comparable level of image noise when compared to scenarios without the SR-Pb shield [10]. Furthermore, its application in the gonads exhibited a remarkable capacity to decrease doses down to 66.9% [11]. The SR-Pb eye shield with a concentration of 95-5 wt% led to a 50% reduction in doses [12]. It was also reported that the SR-Pb eye shield ensures diagnostic optimization without compromising image quality [12].

However, considering the widespread incorporation of TCM feature in modern CT and important of SR-Pb shield [13], this study aims to compare the effectivity of SR-Pb eye shields and TCM technique during head CT examinations. The measurements were conducted using Optically Stimulated Luminescence Dosimeter (OSLD) as the point dosimeter, rendering them suitable for measuring doses on the lens [14].

II. METHODS AND MATERIAL

A. Synthesis of SR-Pb

In this study, a 95-5 wt% SR-Pb eye shield was crafted with dimensions of 17 cm ×17 cm × 0.6 cm. SR-RTV52 Silicone Rubber was synthesized with lead (II) acetate trihydrate (Pb (CH3COO)2-3H2) using the sol-gel method [12]. The process for the fabrication of the 95-5 wt% SR-Pb eye shield is illustrated in Figure 1. The SR-Pb was cut to resemble the shape of eye goggles.

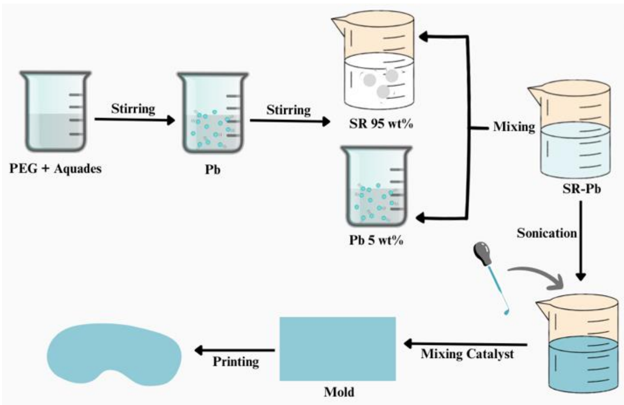


Figure 1. Synthesis of 95-5 wt% SR-Pb eye shield.

B. Dose Measurement

Dose measurements on the lens of the anthropomorphic head phantom were conducted using OSLD nanoDots. The phantom was scanned using a Siemens Somatom Force 576-slice CT Scanner (installed at RSUD Dr. Moewardi, Indonesia). The OSLD was positioned in the central area of surface of the phantom's eye, as depicted in Figure 2 (a), while the eye shield was placed on top of the detector as illustrated in Figure 2 (b). The measured dose on the OSLD was read using an OSLD reader (at the Agency for Research and Innovation (BRIN), Indonesia).

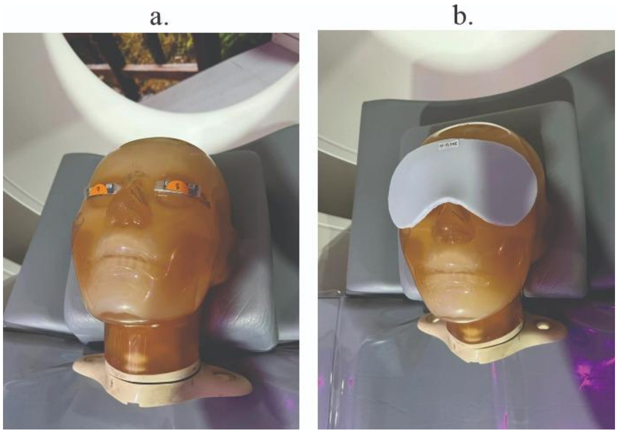


Figure 2. Positioning of (a) OSLD at surface area of the phantom's eye and (b) the SR-Pb eye shield placement on the anthropomorphic head phantom.

Dose measurement was performed with one OSLD package consisted of three detectors on both sides of the eyes. The scanning parameters for the dose measurement are presented in Table 1.

C. Image Noise Evaluation

Image noise was quantified by calculating the standard deviation (SD) of the CT numbers (HU) within specified region of interests (ROIs). These ROIs were strategically positioned in three regions: the right eye, the left eye, and the central area of the head, as illustrated in Figure 3. The mean SD for each imaging technique will be presented.

Figure 3. Region of Interests (ROIs) positioning for noise measurement. Each ROI size is approximately 100 mm².

Table 1. Scanning parameters.

Scanning Parameters	Without SR-Pb and TCM	With SR-Pb Shield	With TCM
Tube voltage (kV)	80, 100, 120	80, 100, 120	80, 100, 120
Tube current (mA)	250	250	Modulated
Scanning mode	Axial	Axial	Axial
Time rotation (s)	1	1	1
Slice thickness (mm)	0.75	0.75	0.75

III. RESULTS AND DISCUSSION

A. Radiation Dose

Measured doses on surface of eyes without SR-Pb and TCM, with SR-Pb, and with TCM for tube voltages of 80, 100, and 120 kV are shown in Figure 4. At each voltage variation, lower radiation doses were found when SR-Pb shielding and TCM techniques were applied compared to without SR-Pb and TCM technique. The use of SR-Pb shield could reduce the dose by 45.28%, while the activation of TCM technique could reduce the dose by 24.78% compared to the dose without SR-Pb and TCM technique at 80 kV. At 100 kV, the dose reduction capabilities of each optimization technique were slightly different; SR-Pb shield could reduce by 31.24%, and TCM could reduce by 18.54%. At 120 kV, SR-Pb shield could reduce the dose by 23.16%, and the TCM technique by 20.19%. This indicates that the dose reduction capability demonstrated using SR-Pb shield with a composition of 95-5 wt% is slightly higher than the use of TCM technique. However, it should be noted that the TCM technique used in this study adhered to the strength level of 50%.

B. Image Quality

Images obtained without SR-Pb and TCM, with SR-Pb, and with TCM at various voltages are shown in Figure 5. It can be seen that the use of SR-Pb does not cause artifacts in nearby areas, i.e., in the eye area. Of course, in areas far from the SR-Pb material there are no more artifacts. Meanwhile, the use of TCM does not cause artifacts, as it is well-known. Visually, the noise in the image using SR-Pb or TCM is similar to that the original image, i.e., without SR-Pb and TCM.

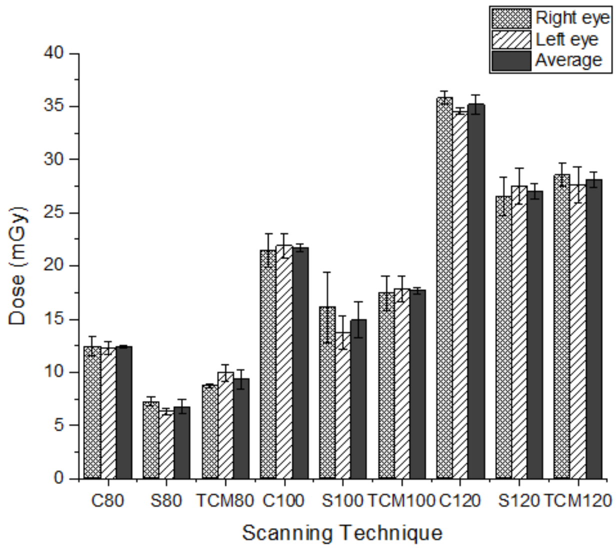


Figure 4. The graphs of measured doses on surface of eyes without SR-Pb and TCM, with SR-Pb, and with TCM for tube voltages of 80, 100, and 120 kV. "C" represents dose without SR-Pb and TCM, “S” represents dose with SR-Pb, and TCM represents dose with TCM technique.

Measured noises on both eyes and center head without SR-Pb and TCM, with SR-Pb, and with TCM for tube voltages of 80, 100, and 120 kV are shown in Figure 6(a). It is clear that eye noise increases with SR-Pb when compared to without SR-Pb. The increase in noise is higher with SR-Pb when compared to using the TCM technique. This phenomenon was obtained at all tube voltages used. An interesting result was that the pattern of increasing noise was also observed in the ROI placed at the center of the head. However, it can be said that the increase in noise when using the SR-Pb or TCM technique is still relatively small.

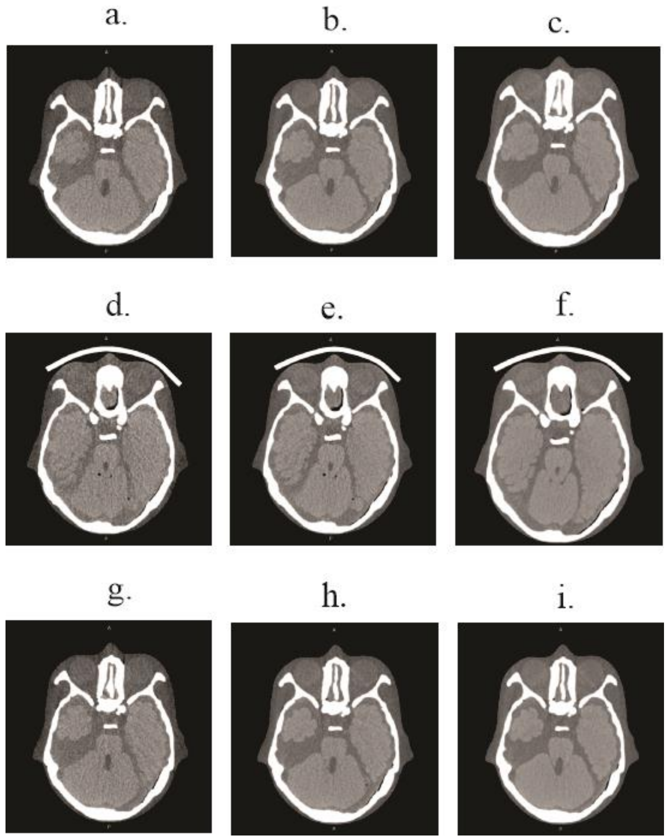


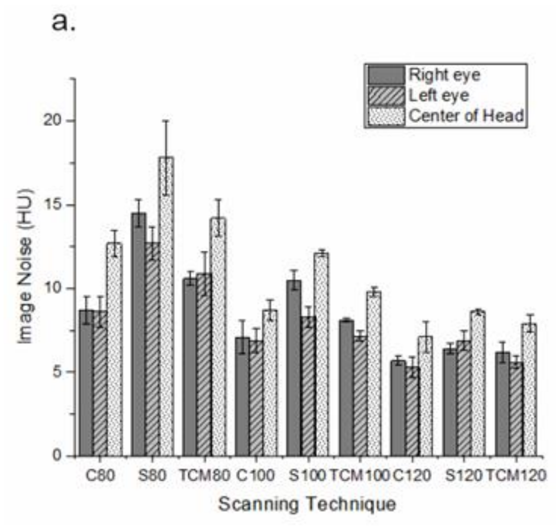
Figure 5. Images obtained without SR-Pb and TCM (a-c), with SR-Pb (d-f), and with TCM (g-i) at various voltages of 80, 100, and 120 kV.

While measured CT numbers on both eyes and center head without SR-Pb and TCM, with SR-Pb, and with TCM for tube voltages of 80, 100, and 120 kV are shown in Figure 6(b). It appears that the use of SR-Pb or TCM does not change the CT number value in the eye area or center of the head. This shows that the use of SR-Pb or TCM does not cause artifacts. This phenomenon was also obtained at all tube voltages used.

The results of this study suggest that SR-Pb can be an alternative for eye dose reduction if TCM techniques are not available. However, this study has several limitations: First, TCM is used with only one strength. A comparative study of dose reduction using SR-Pb shield and TCM with several strengths needs to be carried out in further study. Second, this study only used a head phantom of one size. Comparative studies of dose reduction with SR-Pb and TCM for phantoms with varying sizes need to be carried out to evaluate the impact of SR-Pb or TCM more comprehensively.

IV. CONCLUSION

From this study, it could be concluded that the use of SR-Pb reduced eye dose the use of TCM. It was found that a greater dose reduction was obtained when using SR-Pb compared to using TCM. Meanwhile, the use of SR-Pb led to slightly increasing noise and changing the CT number. In this study, the SR-Pb ratio was 95-5 wt%. Hence, the use of SR-Pb eye shield can serve as an optimistic alternative for radiation optimization in CT machines that do not support TCM mode.



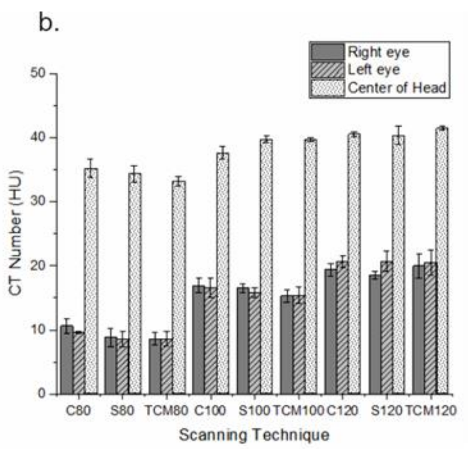


Figure 6. (a) The graphs of measured noises on surface of eyes without SR-Pb and TCM, with SR-Pb, and with TCM for tube voltages of 80, 100, and 120 kV. (b) The graphs of measured CT number. "C" represents dose without SR-Pb and TCM, "S" represents dose with SR-Pb, and TCM represents dose with TCM technique.

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Cite this article as :

Neni Eka Wulandari, Heri Sutanto, Choirul Anam, Hasnel Sofyan, Alviana Hapsari Purbarani, "A Comparative Analysis between SR-Pb Shield and TCM in Eye Dose of Head CT Examination", International Journal of Scientific Research in Science and Technology (IJSRST), Online ISSN : 2395-602X, Print ISSN : 2395-6011, Volume 10 Issue 6, pp. 408-413, November-December 2023. Available at doi : https://doi.org/10.32628/IJSRST52310683

Journal URL : https://ijsrst.com/IJSRST52310683