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Literature study on the evaluation of lead apron thickness in radiology service units

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ABSTRACT

Radiation protection is an effort that can be undertaken to reduce the dangers of radiation. The ALARA principle of radiation protection is needed to minimize the radiation exposure received by workers based on three components: exposure time, distance, and the use of protective equipment. Therefore, an analysis of the effectiveness of lead aprons in protecting workers from radiation exposure is conducted. The method employed involves conducting a literature review on three journals discussing the effectiveness of lead aprons in protecting workers from radiation exposure based on varying apron thicknesses and exposure factors. At 100 kVp tube voltage, a lead apron with 0.25 mmPb thickness and exposure time of 100 mAs has an effectiveness of 25% (15 years old) and 98.1% (3 years old), while a thickness of 0.35 mmPb with an exposure time of 5 mAs has an effectiveness of 93%. At 70 kVp tube voltage, a lead apron of 0.35 mmPb thickness with an exposure time of 5 mAs has an effectiveness of 98.4%. A 0.5 mmPb lead apron with exposure times ranging from 20 mAs to 72 mAs has an effectiveness between 93.75% and 99.219%. The effectiveness of a lead apron is influenced by tube voltage, exposure time, age, and quality of the lead apron. A thick apron does not necessarily have high effectiveness in protecting workers if it has poor quality, and vice versa.

Keywords: Dose; lead apron; radiation protection; radiology

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INTRODUCTION

Radiation worker protection, also known as radiation protection, is an effort to reduce the dangers of radiation. Therefore, the principle of ALARA (As Low As Reasonably Achievable) radiation protection is needed to minimize radiation exposure received by workers based on three components: exposure time, which refers to the length of time a person is exposed to radiation; distance, which refers to how far a person is from the radiation source; and use of shielding, which refers to whether the person near the radiation source is equipped with shielding capable of protecting them from direct radiation exposure.

According to BAPETEN Regulation No. 8 of 2011, every service provider must have radiation protection equipment with a minimum of 0.25 mmPb, and its size/design must provide adequate protection to the user's body and gonads from direct radiation [1]. The protective equipment in question includes Pb aprons, Pb goggles, Pb gloves, Pb thyroid protectors, and gonad protectors. Protective equipment with a thickness equivalent to 0.25 mmPb can withstand radiation up to 100 kVp. However, increasing the exposure factors (tube voltage and exposure time) will affect the amount of radiation received. This is because tube voltage affects the radiation's penetration power, and exposure time affects the dose. Therefore, a thicker apron is required.

Based on this, an analysis was conducted on the effectiveness of aprons in protecting workers from radiation exposure with varying thicknesses: 0.25 mmPb, 0.35 mmPb, and 0.5 mmPb. This was done to determine the effectiveness of the aprons used in protecting workers from radiation exposure.

RESEARCH METHODS

This research was conducted using a literature review method, compiling references from several previous studies and then compiling them into a conclusion [2].

The data analysis technique used in this study was content analysis to obtain valid data. The analysis involved sorting, comparing, combining, and selecting data to obtain relevant data [3]. The journals analyzed were "Radiological Evaluation of Lead Apron Integrity in Five Selected Hospitals in Abuja, Nigeria" [4] as the first journal; "Analysis of the Effectiveness of 0.35 mmPb Apron in Protecting Radiation Workers in Radiography Examination" [5] as the second journal; and "Evaluation of the Adequacy of Lead Apron Thickness to Support Radiation Safety Assurance in Hospital Radiology Service Units" [6] as the third journal. These three journals were then analyzed to obtain a conclusion.

RESULTS AND DISCUSSION

This study compared the effectiveness of aprons in protecting workers from radiation exposure based on their thickness: 0.25 mmPb, 0.35 mmPb, and 0.5 mmPb.

Based on the first journal, "Radiological Evaluation of Lead Apron Integrity in Five Selected Hospitals in Abuja, Nigeria" [4], an evaluation of lead apron quality was conducted. An X-ray source, an Optically Stimulated Luminescence Dosimeter (OSLD) as the detector, and a lead apron with a thickness equivalent to 0.25 mmPb were used. The exposure factors applied to the source were 100 kVp and 100 mAs; and the measurement distance used was 100 cm. The measurement procedure involved placing the OSLD before and after the apron and phantom to determine the dose received (incoming dose) and the dose transmitted (outgoing dose). The obtained data was then processed to obtain the percentage transmitted dose using Equation (1).

$$Transmission\, T = \frac{Dose\ out}{Dose\ in} \times 10 \qquad (1)$$

This yields a transmitted dose percentage of 75% for 15-year-old lead apron A, with an incoming dose of 0.12 Gy and an outgoing dose of 0.09 Gy. For 3-year-old lead apron B, the transmitted dose percentage was 1.9%, with an incoming dose of 0.108 Gy and an outgoing dose of 0.02 Gy.

Based on the second journal article, "Analysis of the Effectiveness of 0.35 mmPb Aprons in Protecting Radiation Workers in Radiography Examination" [5], a test was conducted on the effectiveness of aprons with a thickness equivalent to 0.35 mmPb on radiation workers during radiography examinations. The analysis was conducted using a GE multipurpose 500 mA X-ray machine as the radiation source, a radiation multidetector as the detector, and an anthropomorphic phantom as the target. The radiation exposure measurement procedure involved positioning the detector above the phantom to obtain radiation exposure data without an apron, or as described in the data as "non-apron." The apron was then placed over the detector to obtain radiation exposure data when using an apron, or as described in the data as "apron." The exposure factor was adjusted with varying tube voltages of 45-100 kVp and exposure times of 5 mAs; a measurement distance from the X-ray tube to the detector of 100 cm; and varying the irradiation field sizes, namely 18 × 24 cm and 43 × 35 cm.

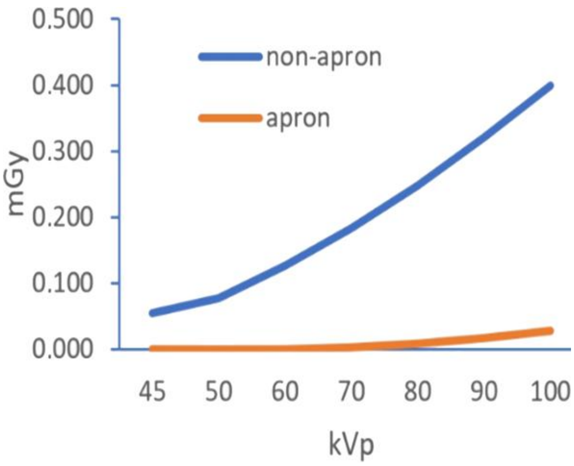

Figure 1. Radiation exposure measurement curve in an 18 × 24 cm irradiation field.

In the irradiation fields of 18 × 24 cm (Figure 1) and 43 × 35 cm (Figure 2), with varying tube voltages of 45-100 kVp, the radiation exposure results were the same for the "non-apron" (0.050 – 0.400 mGy) and for the "apron" (0 – 0.020 mGy).

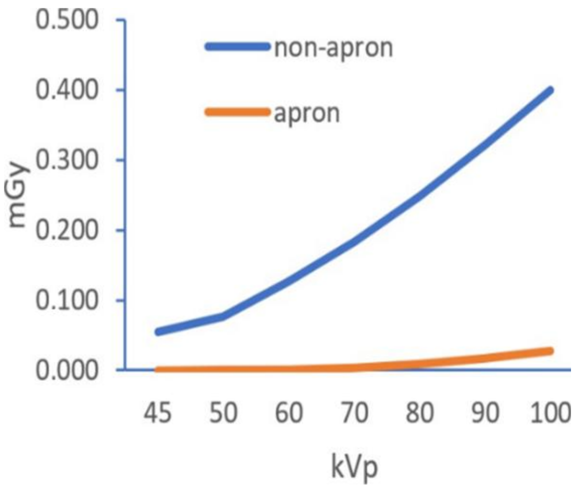

Figure 2. Radiation exposure measurement curve in an 43 × 35 cm irradiation field.

A calculation was then performed to determine the percentage effectiveness of the apron used, using Equation (2).

$$Eff\ (\%) = \left(1 - \frac{apron\ exposure\ (mGy)}{non-apron\ exposure\ (mGy)}\right) \times 100 \quad (2)$$

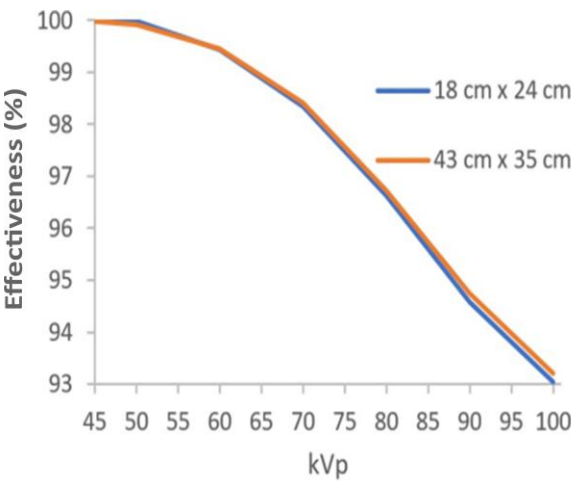

Figure 3. Curve of the effect of tube voltage on the effectiveness of a 0.35 mmPb lead apron.

The percentage effectiveness of the apron is depicted in the curve (Figure 3), where the apron with a thickness equivalent to 0.35 mmPb and a tube voltage variation of 45 – 100 kVp is 93% – 100%.

Based on the third journal, "Evaluation of the Adequacy of Lead Apron Thickness to Support Radiation Safety Guarantees in Hospital Radiology Service Units" [6], an evaluation was conducted to determine the adequacy of lead aprons with a thickness equivalent to 0.5 mmPb in each radiology unit in hospitals in Semarang. This evaluation was conducted using a conventional X-ray machine as a radiation source, which was directly fired at an apron with a thickness equivalent to 0.5 mmPb, which was stretched on an examination table at a distance of 100 cm from the X-ray tube. Two dose rate measurement conditions were performed: the dose rate before passing through the lead apron and the dose rate after passing through the lead apron. Using 11 apron samples obtained from four different radiology units with the same thickness, but exposed to X-rays with different exposure factors, the HVL value was calculated using Equation (3).

$$D_t = D_0 \left(\frac{1}{2}\right)^{\frac{x}{HVL}} \quad (3)$$

where:

D_t = dose rate after passing through the lead apron.

D_0 = dose rate before passing through the lead apron.

x = lead apron thickness.

HVL = lead apron thickness.

In radiology unit A, irradiation was performed on two aprons with an exposure factor of 70 kV and 40 mAs, resulting in a dose rate transmitted to both aprons of 6.25%, with an HVL value of 4 HVL. In radiology unit B, irradiation was performed on two aprons with the lead aprons in the condition shown in Figure 4, with cracks on the bottom and sides of the aprons. Irradiation was performed with an exposure factor of 70 kV and 20 mAs, resulting in a dose rate transmitted to both aprons of 6.25%, with an HVL value of 4 HVL. In radiology unit C, irradiation was carried out on 2 (two) lead aprons with an exposure factor of

70 kV and 72 mAs, the dose rate transmitted by both aprons was 6.25% and the HVL value was 4 HVL. In radiology unit D, irradiation was carried out on 6 (six) lead aprons with an exposure factor of 70 kV and 30 mAs, the dose rate transmitted by the five aprons was 3.125% and the HVL value was 5 HVL; and the dose rate transmitted by the only apron in radiology unit D was 0.781% and the HVL value was 7 HVL. The linear attenuation coefficient was then calculated using Equation (4).

$$\mu = \frac{\ln 2}{HVL} = \frac{0,693}{HVL} \tag{4}$$

This concludes that the attenuation coefficient and HVL are inversely proportional, where the larger the HVL, the smaller the linear attenuation coefficient.

According to Aizah, the larger the exposure factor applied, the greater the resulting exposure dose, thus requiring thicker protective equipment to protect against radiation exposure; in this case, the protective equipment in question is a lead apron [7]. However, several factors can influence the effectiveness of the lead apron, one of which is ensuring the quality of the lead apron used.

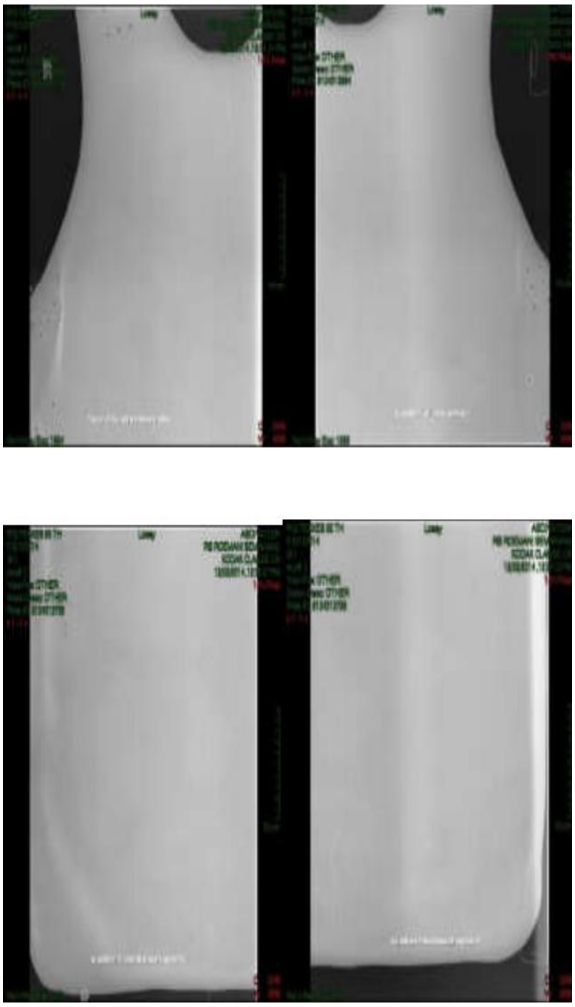

Figure 4. Results of lead apron irradiation in radiology unit B.

Table 1. Results of the lead apron effectiveness evaluation.

Journal	Tube voltage (kVp)	Exposure time (mAs)	Apron thickness (mmPb)	Effectiveness (%)
2	70	5	0.35	98.4
3		20	0.5	93.75
		40		93.75
		30		93.75
		72		96.88
1	100	100	0.25 (3 year)	98.1
			0.25 (15 year)	2
2		5	0.35	93

Based on the results obtained from the analysis of the effectiveness of lead aprons at thicknesses of 0.25 mmPb, 0.35 mmPb, and 0.5 mmPb through a literature review of three scientific journals, the percentage value of lead apron effectiveness was obtained using Equations (5) and (6).

$$Eff\ (\%) = 100\% - rate\ dose\ (\%) \tag{5}$$

$$Eff\ (\%) = 100\% - transmitted\ dose\ (\%) \tag{6}$$

At a tube voltage of 100 kVp, lead aprons A (age 15) and B (age 3) with a thickness of 0.25 mmPb and an exposure time of 100 mAs have a transmitted dose of 75% and 1.9%, respectively, meaning the lead apron's effectiveness is 25% and 98.1%, respectively. This is due to the difference in age of the lead aprons. Meanwhile, a 0.35 mmPb lead apron with an exposure time of 5 mAs has a 93% effectiveness. In this case, the apron thickness does not affect its effectiveness in protecting against radiation exposure. The radiation dose delivered to the 0.25 mmPb lead apron is greater than that delivered to the 0.35 mmPb lead apron. However, the 0.25 mmPb lead apron is 98% effective.

At a tube voltage of 70 kVp, a lead apron with a thickness of 0.35 mmPb with an exposure time of 5 mAs, has an effectiveness percentage of 98.4%. Meanwhile, for a lead apron thickness of 0.5 mmPb with an exposure time of 20 mAs, 40 mAs, 30 mAs, 72 mAs, respectively, has an effectiveness percentage of 93.75%, 93.75%, 93.75%, and (96.875% and 99.219%). Based on (Aizah, 2023), mAs affects the dose generated by an X-ray radiation exposure. However, in the case of a lead apron with a thickness of 0.5 mmPb, there is an increase in the effectiveness percentage when the exposure time is increased (40 mAs to 72 mAs). This is very possible to occur, seen from the number of samples used for testing, namely 12 lead aprons. It is very possible that the members of the sample are aprons with the same thickness but have different qualities.

CONCLUSION

Based on the literature review, it was concluded that at a tube voltage of 100 kVp, a 0.25 mmPb lead apron (aged 3 years) with an exposure time of 100 mAs had a higher effectiveness percentage than a 0.35 mmPb lead apron with an exposure time of 5 mAs, at 98.1%. At a tube voltage of 70 kVp, a 0.35 mmPb lead apron with an exposure time of 5 mAs had a higher effectiveness percentage than a 0.5 mmPb lead apron with exposure times of 20 mAs, 40 mAs, 30 mAs, and 72 mAs, at 98.4%.

Factors that influence the effectiveness of lead aprons as personal protection from radiation exposure include: the specified exposure time, as this will affect the resulting dose; the age of the lead apron; and the quality of the lead apron; the presence of cracks and/or other conditions. Because it has been proven that good quality lead aprons are more effective in protecting yourself from radiation exposure compared to thick lead aprons of poor quality.

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