Criteria have been developed to aid in determining when lead aprons should be discarded.

Inspection of Lead Aprons: Criteria for Rejection

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Abstract: *Lead aprons utilized by personnel performing fluoroscopy are routinely inspected for damage to comply with the requirements of hospital accrediting organizations. Fluoroscopic or radiographic examination of lead aprons may reveal imperfections ranging from small pinholes to large tears. Currently, there are no standards establishing a criteria for acceptance or rejection of lead aprons. As a consequence, many facilities have established arbitrary rejection criteria. Often lead aprons are discarded due to small imperfections, a practice that can become costly to these institutions. We have calculated increases in doses to the whole body for varying sizes of holes, including special consideration of the effects on effective dose equivalent when the hole is over the testes and thyroid. ALARA standards for cost per person-sievert averted are used to establish a rational basis for criteria of acceptance or rejection of lead aprons. Health Phys. 80(Supplement 5): S67–S69; 2001*

Key words: *operational topics; occupational safety; ALARA; fluoroscopy*

INTRODUCTION

To reduce radiation exposure, fluoroscopic unit operators are required to wear protective lead aprons. The lead is actually lead-impregnated vinyl or rubber with a shielding equivalent given in millimeters of lead. Some aprons use a combination of lead and other attenuating material to make the apron lighter while maintaining an equivalent shielding ability. The lead-impregnated vinyl apron typically has a nylon fabric as a finished outer material.

In use, the aprons are subject to both normal wear and abuse. The aprons can be folded and creased, dropped on the floor in such a way as to cause sharp bends in the vinyl, or otherwise misused. The deterioration of the lead-impregnated vinyl is manifested as cracks or holes in the shielding. These can be seen radiographically or fluoroscopically. Figs. 1–3 show radiographs of damaged lead aprons. Annual inspections of lead aprons are required by the Joint Commission on the Accreditation of Healthcare Organizations (JCAHO 1983). There are, however, no regulatory or scientific standards establishing rejection criteria for lead aprons. As a result, individual medical facilities establish rejection criteria based on their own volition.

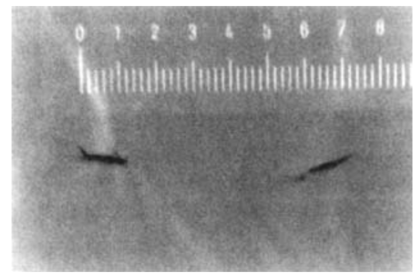

Figure 1. Radiograph of lead apron with cracks. Scale in centimeters.

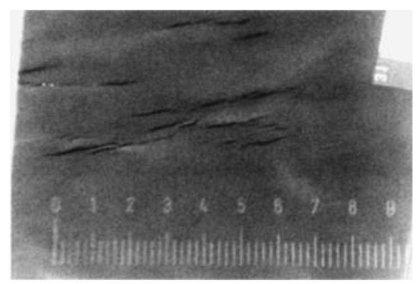

Figure 2. Radiograph of lead apron with multiple cracks. Scale is in centimeters.

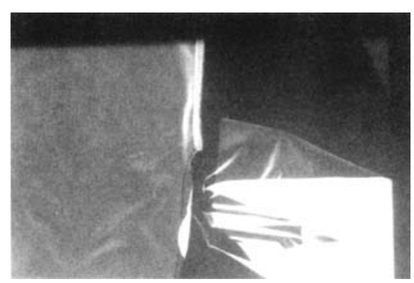

Figure 3. Radiograph of lead apron with detached lead in back of panel of apron. Left side is intact side panel, dark upper right area is absent of lead, light lower right area is multiple folds of lead.

DISCUSSION

The philosophy of keeping doses as low as reasonably achievable (ALARA) was used to establish the rejection criteria. With ALARA, reasonable can be defined as a dollar amount spent to avert a given dose. This has not been used in medical health physics; however, it is common practice in the nuclear power industry. The most common value used by the nuclear power indus-

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try is \$1,000 per millisievert averted (NARTC 19XX).

Replacing a lead apron averts an increase in dose due to defects in the apron. Therefore, the replacement cost of the lead apron is the amount spent to avert the dose due to a defective lead apron. Lead apron prices range from \$400 to over \$700. By simple ratio and using \$400 as the most conservative cost, a dose criteria of 0.4 mSv due to a defect in the lead apron was established.

A simple mathematical model of increasing doses with increasing sizes of defects was developed as follows:

Dose Equilvalent (1)

$$= w_t \times D \times f \times \left(1 - \frac{a}{A}\right) + w_t \times D \times \left(\frac{a}{A}\right)$$

where

- w_t = tissue weighting factor;
- D = unattenuated whole body dose equivalent to the individual;
- f = transmission fraction;
- a = area of defect; and
- A = cross-sectional area of the lead apron (frontal view).

The additional dose from the defect is then given by

Additional Dose (2)

$$= \left[w_t \times D \times f \times \left(1 - \frac{a}{A}\right) + w_t \times D \times \frac{a}{A}\right] \times w_t \times D \times f$$

$$= w_t \times D \times \frac{a}{A} - (1 - f).$$

For the whole body let,

$w_t = 1$,
$D = 250$ mSv,
$f = 0.05$,

and

$A = 4{,}000\ \text{cm}^2$.

D is based on the following two assumptions:

1. A busy fluoroscopist may typically receive an unattenuated dose equivalent of 50 mSv (5 rem) per year; and
2. The expected life of a properly cared for lead apron is 10 y. The average age of lead aprons and the average remaining life of lead aprons at a facility is approximately 5 y.

Therefore, the total dose is 50 mSv $\text{y}^{-1} \times 5$ y = 250 mSv.

Increases in dose equivalent with increasing size of the defect is shown in Fig. 4.

From the graph, aprons should be rejected and replaced if the sum of the areas of defects exceeds 670 mm^2 (equivalent to a 29 mm diameter circular hole) (based on our dose criteria of 0.4 mSv).

The same model can be used to determine effective dose equivalent should the defect be positioned such that a "critical organ" is exposed. Two "critical organs" were considered. The gonads were considered because the tissue weighting factor is high, and the thyroid was considered because separate shielding (thyroid shield) is often used for protection. (For added conservativism, effective dose equivalent was used rather than effective dose because the tissue weighting factor for the gonads is higher.) Further, male gonads provide the worst case because overlying tissue absorption for the female gonads would significantly reduce the organ dose. In this case, A is the cross sectional area of the organ, 2,200 mm^2, and w_t is the tissue weighting factor for the gonads, 0.25. All other values are the same as previously stated.

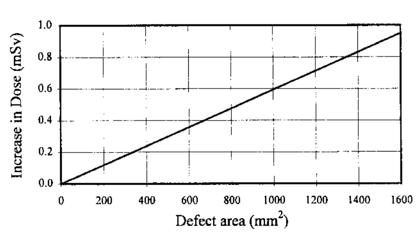

Figure 4. Increase in dose due to defect in lead apron.

Figs. 5 and 6 are the results for the gonads and thyroid respectively. Note that the criteria for the thyroid is 0.04 mSv. This is because the replacement cost for a thyroid shield is \$40, an order of magnitude lower than replacement cost for aprons.

From the graphs, aprons should be rejected and replaced if the sum of the areas of defects exceeds 15 mm^2 (equivalent to a 4.3 mm diameter circular hole) if the defect is over the testes and thyroid shields should be rejected and replaced if the sum of the areas of defects exceeds 11 mm^2 (equivalent to a 3.8 mm diameter circular hole).

Although the authors believe reasonably conservative values were used to establish the above rejection criteria, other institutions may choose different values (e.g., \$200 per millisievert averted) to determine their rejection criteria. Therefore, the general case is

rejection criteria

$$= \frac{(\text{lead apron cost}) \times A}{w_t \times D \times (1 - f) - (\text{cost per unit dose averted})},$$

where all the values have been previously defined. It should be noted that the area, A, needs to correspond to the organ or tissue for which the tissue weighting factor, w_t, is specified.

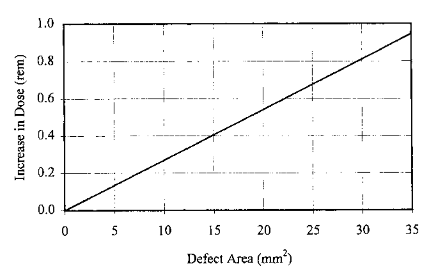

Figure 5. Increase in dose due to defect over testes.

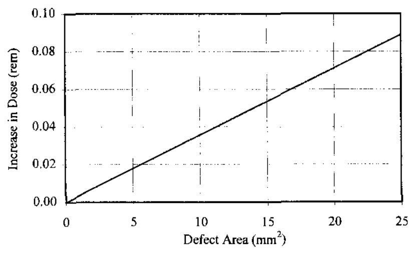

Figure 6. Increase in dose due to defect in thyroid shield.

RECOMMENDATIONS

The intent of calculating the dose increase that would occur should the defect occur over the gonads was to establish a rejection criteria based on the worst case. Therefore, it is recommended that lead aprons be replaced if a defect is greater than 15 mm^2 unless the defect is clearly not over a critical organ. Lead aprons with defects along the seam, in overlapped areas, or on the back of the lead apron would be subject to the less conservative 670 mm^2 rejection criteria. Thyroid shields with defects greater than 11 mm^2 should be replaced.

CONCLUSION

Medical and medical health physicists routinely apply basic ALARA principles to determining shielding requirements for rooms where x-ray producing equipment is used. Similarly, it is appropriate to use ALARA to determine when to replace protective lead aprons. Although a more rigorous model for determining dose to specific organs due to defects in lead aprons could be developed, the simple model described in this paper is adequate for establishing rejection criteria based on ALARA principles.

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