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

Inspection of Lead Aprons: Criteria for Rejection

Kent Lambert and Tara McKeon*

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 S): 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 are known 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.

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-
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 Equivalent

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

Additional Dose

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

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

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

For the whole body let,

- \(w_t = 1\),
- \(D = 250\) mSv,
- \(f = 0.05\),

and

\(A = 4,000\) cm².

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

\[
D = 250\text{ mSv} \times 0.05 = 12.5\text{ mSv}
\]

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

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


North American ACARA Center, College of Engineering, University of Illinois.