Optimizing radiation protection of the operator during cardiac catheterization by minimizing the effective dose

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Abstract. Radiation exposure dosimetry for the personnel is based on measurements of phantom studies. To determine effective dose values for different X-ray equipment, TLD-measurements were performed using an Alderson Phantom in the patient position and a second phantom in the typical position of the personnel. Various types of protective clothing as well as fixed shields were considered in the calculations. Additional thyroid protection collars reduce the effective dose by a factor of 1.8-2.6. In the sense of effective dose X-ray protective clothing with 0.35 mm lead equivalent and an additional thyroid protection collar provide a better protection against radiation than an apron with 0.5 mm lead equivalent without collar. The doses of the unshielded organs (thyroid, parts of the active bone marrow) contribute significantly to the effective dose of the staff. Therefore an additional shielding of these organs reduces the effective dose more than an increase of the lead equivalency of the existing apron. We recommend face shields and thyroid protection collars as a necessary part of anti-X protection for cardiac catheterization laboratories.

KEYWORDS: Coronary angiography; radiation exposure; occupational radiation protection; radiation protection devices; thyroid protection collar

1. Introduction

Various radiation protection devices are available for the personnel in cardiology: Lead curtains or lead acrylic glass shields are not generally used in all catheterization laboratories. Aside from strict adherence to established and newer techniques to minimize radiation exposure the individual doses can vary considerably depending on lead equivalency and design of X-ray protection garments. This requires some attention in order to establish a balance regarding protective features, spine lesion risk, and acquisition investment.

The actual effect of the different protection devices is difficult to assess. In radiation protection the effective dose provides a quantitative measure for the probability of stochastic effects. Therefore in this study the quality of radiation protection devices is evaluated based on the extent to which the effective dose of a staff member is reduced. The whole-body exposure of the personnel is measured typically with film-badge worn on the anterior chest region of the body underneath the protective clothing. Due to this one-spot-measurement the influence of different types of protective aprons and additional protective garment on the effective dose of an individual cannot readily be determined without phantom studies.

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2. Materials and Methods

Measurements were performed in a cardiac catheterization laboratory equipped with a single plan cineangiography unit (Integris, Philips Medical Systems) with an undetachable X-ray tube.

Radiation exposure dosimetry for the personnel is based on measurements of phantom studies. To determine effective dose values for different X-ray equipment, measurements were performed using a male Alderson Phantom in patient position to generate radiation scatter and a female Alderson Phantom in typical position of the operator. To optimize the measurement exactness the measurements were carried out without making use of protective aprons and additional protective garment. Various types of personal radiation protection garment as well as fixed shields were later considered mathematically in the calculations.

For dosimetry, thermoluminescence dosimeters (LiF-100 H; Thermo Eberline Trading / Harshaw) were inserted into the operator phantom at multiple organ-specific locations. For each recording, at least 90 dose measurements were made according to a standardized protocol [1]. The effective doses were calculated on the basis of ICRP 60 [2].

The effect of lead apron on the effective dose in the Alderson Phantom measured without radiation protection was derived using published data on the amount of scattered radiation passing through lead [3]. Values for a typical average high voltage of 87.5 kV (0.35 mm lead: 6.04%; 0.5 mm lead: 3.30%) were estimated by interpolation. The values refer to the ambient dose equivalent H*(10) which is an approximation of the effective dose.

The effect of lead side shielding was derived from the dose reduction factors previously published by von Boetticher et al. [1]. To account for differences in dose reduction between the upper and the lower body, two different reduction factors were applied, i.e. for the head, thorax and abdominal organs, the factor 3.96 was used, for the pelvis the factor 10.3 was used.

3. Results

Effective doses for the staff are provided in Tab. 1, assuming use of protective garment with 0.35 and 0.5 mm lead equivalent, respectively. Separate values were calculated considering no shielding, and shielding of only the lower part of the body and of the lower and the upper part, respectively. For all doses the effect of an additional thyroid protection (lead equivalent 0.5 mm) was determined. Effective doses are relative to the respective values of a person without protective garment and no installed shielding. The last column provides the ratio between effective doses with and without thyroid protection.

The additional shielding of the thyroid has an important influence on the magnitude of the effective dose: Additional thyroid protection collars reduce the effective dose by a factor of 1.8-2.6.

In the case of no thyroid protection, an increase in lead equivalent of the protective apron from 0.35 to 0.5 reduces the transmission by a factor of 1.83. The effective dose, however, decreases only by a factor of 1.22. Hence the impact of a more efficient apron on the effective dose is only marginal. A combination of an apron with 0.35 mm lead equivalent with a thyroid protection collar, however, reduces the effective dose considerably (Tab. 1). This combination is 1.5 times more efficient in terms of a reduction of the effective dose as is the use of a protective apron with 0.5 mm lead equivalent without thyroid protection. At the same time the combination reduces the total weight of the protective clothing considerably.
4. Discussion

Our analysis reveals significant differences between the protective efficiency of different protective garments and their effect on the effective dose (Tab. 1).

Shielding factors for protective garment can readily be misinterpreted: the attenuation factor of protective garment should not be confused with a reduction of the effective dose due to the garment. Particularly, it is not possible to extend a reduction of the transmission by a factor of almost 2 to a similar reduction in effective dose.

These systematic differences are a consequence of the major contribution of organs not covered by the protective apron (particularly the thyroid gland and parts of the red bone marrow) to the effective dose of a person in routine work situations. A reduction of the exposure to these organs considerably reduces the effective dose. A further reduction of the exposure to organs already shielded by protective garment – e.g. by means of higher lead equivalence aprons, has only a limited effect on the effective dose since it ultimately refers to a weighted sum of organ doses.

Table 1: Relative effective doses for different radiation protection devices during coronary angiography and catheter intervention. Factor f = effective dose without thyroid protection collar / effective dose with thyroid protection collar.

<table>
<thead>
<tr>
<th>Relative effective doses</th>
<th>without thyroid protection collar</th>
<th>with thyroid protection collar</th>
<th>f</th>
</tr>
</thead>
<tbody>
<tr>
<td>without radiation protection</td>
<td>100 %</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>lead apron 0.35 mm Pb</td>
<td>12.0 %</td>
<td>6.59 %</td>
<td>1.8</td>
</tr>
<tr>
<td>lead apron 0.50 mm Pb</td>
<td>9.87 %</td>
<td>4.43 %</td>
<td>2.2</td>
</tr>
<tr>
<td>lead apron 0.35 mm Pb + Pb side shield</td>
<td>8.94 %</td>
<td>3.50 %</td>
<td>2.6</td>
</tr>
<tr>
<td>lead apron 0.50 mm Pb + Pb side shield</td>
<td>8.75 %</td>
<td>3.32 %</td>
<td>2.6</td>
</tr>
<tr>
<td>lead apron 0.35 mm Pb + face shield + Pb side shield</td>
<td>3.12 %</td>
<td>1.78 %</td>
<td>1.8</td>
</tr>
<tr>
<td>lead apron 0.50 mm Pb + face shield + Pb side shield</td>
<td>2.56 %</td>
<td>1.22 %</td>
<td>2.1</td>
</tr>
</tbody>
</table>
Therefore for example X-ray protective clothing with 0.35 mm lead equivalent and an additional thyroid protection collar provide a better protection against radiation than an apron with 0.5 mm lead equivalent without collar.

Since radiation protection aims to minimize the effective dose, the implementation of ICRP 103 [4] will increase the relevance of the organs in the head and neck region, which are not protected by conventional radiation-protective clothing [5].

5. Conclusions

Typically part of the body of the staff not is shielded by the protection garment. The use of an additional face shield or an additional thyroid protection collar not only works as a preventive measure to avoid exceeding occupational organ dose limits. The doses of the unshielded organs (thyroid, parts of the active bone marrow) also contribute significantly to the effective dose of cardiology staff. Therefore an additional shielding of these organs reduces the effective dose more than an increase of the lead equivalency of the apron. To optimizing radiation protection of the staff we recommend thyroid protection collars as a necessary part of anti-X protection during coronary angiography and intervention.

REFERENCES