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Research Article

Are Antimony-Bismuth Aprons as Efficient as Lead Rubber Aprons in Providing Shielding against Scattered Radiation?

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ABSTRACT

Aim: The aim of this study is to compare the absorption ability of two lead-free aprons with a lead apron.

Method: The absorption ability of three aprons was measured and compared; Opaque Fusion 0.35 mm (OpaqFu) bilayer apron containing bismuth and antimony, No Lead 0.35 mm (NoLead) one-layer apron containing antimony, and a lead apron. The measurements were repeated with and without each of the aprons present in both primary and scattered beams. The selected tube voltages were between 60 and 113 kVp with constant mAs, a fixed field size, and fixed source-to-object distance.

Results: No significant difference in absorption ability of the two lead-free aprons compared with that of the lead apron was observed when the dose was measured in the primary beam. When measurements were performed in the scatter radiation field, the absorption ability of the OpaqFu apron was 1.3 times higher than that of NoLead apron and nearly equal to the absorption ability of the lead apron. An increase in the difference between the OpaqFu and NoLead aprons was observed for the tube energies higher than 100 kVp in favour of OpaqFu apron.

Conclusion: It is safe to use the lead-free aprons that were tested in this study in a clinical environment for the tube energy range of 60 kVp–113 kVp.

RÉSUMÉ

But : Comparer la capacité d'absorption de deux tabliers sans plomb avec un tablier de plomb.

Méthodologie : Mesurer et comparer la capacité d'absorption de trois tabliers: un tablier bicouche OpaqFu contenant du bismuth et de l'antimoine, un tablier monocouche NoLead contenant de l'antimoine et un tablier au plomb. Les mesures ont été répétées avec et sans que chaque tablier soit présent dans des faisceaux primaire et diffusé. Les tensions de tube se situaient entre 60 et 113 kVp à mA constant, une taille de champ fixe et une distance source-objet fixe.

Résultats : Aucune différence significative n'a été constatée dans la capacité d'absorption des deux tabliers sans plomb comparativement au tablier de plomb lorsque la dose a été mesurée dans le faisceau primaire. Lorsque les mesures ont été prises dans le champ de rayonnement diffusé, la capacité d'absorption du tablier OpaqFu était de 1,3 fois supérieure à celle du tablier NoLead apron et presque égale à celle du tablier de plomb. Une augmentation de l'écart entre les tabliers OpaqFu et NoLead a été observée pour les énergies de tube supérieures à 100 kVp en faveur du tablier OpaqFu.

Conclusion : Il est sécuritaire d'utiliser les tabliers testés dans l'étude dans l'environnement clinique pour les valeurs d'énergie comprises entre 60 et 113 kVp.

Keywords: Absorption ability; antimony-bismuth; lead aprons; lead-free aprons; primary and scatter radiation fields

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Introduction

Lead protection garments are a key radiation protection tool against ionizing radiation [1–4]. The variation in protection as a function of x-ray energy is well understood for lead aprons [1]. The disadvantages of lead aprons are toxicity [5] and weight [1,3,6–8]. The possibility of replacing lead with other protective devices of moderate-to-high atomic number elements has previously been investigated [1,3,5,9–11]. Weight reductions of 25% can be achieved for specific energies with lead-free aprons [9], but studies [1,3] have shown that lead-free garments are not as effective in attenuating radiation. However, earlier studies have concluded that most new-generation, lead-free aprons provide sufficient protection and are comparable to lead aprons [5,9]. Bismuth-antimony is one of the materials used as a shielding material for protecting the fetus in computed tomography examinations [12,13]. The same lead-free material used by different manufacturers varies significantly in attenuation capabilities [11]. It is therefore necessary to measure and verify the x-ray attenuation performance of protective apron materials from each manufacturer before clinical use [11]. A healthcare professional is seldom subjected to the direct radiation beam. Most often, the healthcare professional stands beside the imaging table where the patient is positioned and is subjected to scattered radiation. Therefore, the protection capability of aprons from scattered radiation must also be evaluated. To our knowledge, no studies have investigated the x-ray absorption ability of antimony-bismuth aprons in a clinical environment or have directly compared their shielding effect to that of lead-equivalent aprons. Therefore, the aim of this study is to evaluate the x-ray absorption abilities of one commercially available lead apron and compare it with two commercially available aprons made of different combinations of antimony and bismuth. This comparison will be made at different x-ray energies for both primary and scattered beam radiation.

Materials and Methods

One lead and two lead-free aprons were tested for x-ray absorption ability in both primary and scattered radiation fields. The method for the measurements performed in this study (with and without the aprons) is based on methods described in previous studies [5,14–16].

Apron Description

The lead-free aprons were from Scanflex Medical AB (Täby, Sweden): “Opaque Fusion 0.35 mm” (“OpaqFu”) and “No Lead 0.35 mm” (“NoLead”). They consisted of a combination of the two metals—antimony and bismuth. Although OpaqFu and NoLead are made from the same two metals, OpaqFu has been manufactured using a so-called bilayer technique with thinner layers that reduce the weight of the apron [9]. The lead apron was manufactured by Mavig GmbH (Munich, Germany): “Pb 0.35 mm” (“Pb”). All aprons were checked for defects before use. To encompass the use of aprons at higher energies (over 100 kVp), aprons with a specified lead-equivalent thickness of 0.35 mm were selected, as recommended by Institute of Physics and Engineering in Medicine [17].

Measurements in the Primary Radiation Field

A Siemens Multix TOP x-ray unit (Siemens Healthcare GmbH, Erlangen, Germany) with a tungsten anode and inherent filtration of 2.5 mm Al at 70 kVp was used to generate 17 different tube voltages between 60 kVp and 113 kVp, in steps of 2 kVp–4 kVp. For measurements in the primary and scatter beam, a tube current-time product of 10 mAs was used both with and without an apron present in the radiation field (Figure 1). Dose measurements in the primary beam were performed using a Mult-O-Meter (Unfors Instruments AB, Billdal, Sweden). To minimize random error, dose measurements were repeated three times and then

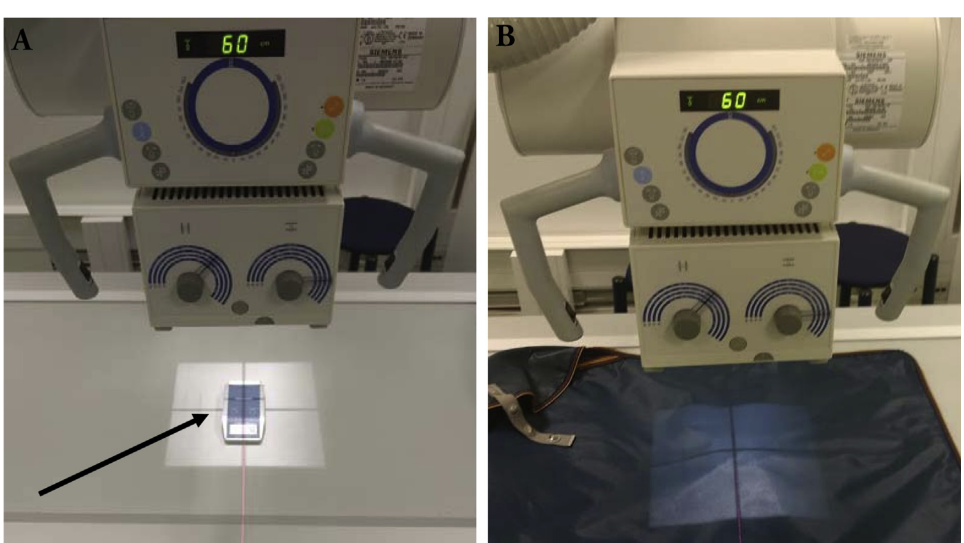

Figure 1. (A) The MOM detector placed without the protective garment. (B) The MOM detector placed in the radiation field (same location as in Figure 1A) behind the protective garment. MOM, Mult-O-Meter.