1. Introduction

- Copper shield is an example of the radioprotective shields used for reducing absorbed X-ray dose to the radiosensitive organs in computed tomography (CT).
- However, copper generates incoherent scattering of X-rays incident to diagnostic X-rays in comparison with bismuth, another material used in commercially available radioprotective shields.

2. Objectives

- To evaluate the effectiveness of adding an aluminum sheet to the copper shield in order to attenuate secondary X-rays generated from the copper shield.

3. Materials

A) Measurement of photon energy spectra
- Photon energy spectra of primary X-ray beams (120-kVP tube voltage and approximately 50-keV effective energy) were obtained using a high-purity germanium detector (GLP-06165/05P; EG&G ORTEC, Oak Ridge, TN) (Fig.1) when a commercially available bismuth sheet (ARB42; F&L Medical Products, Vandergrift, PA), copper plate (0.1–0.3-mm thick and 99.9% pure), or copper plate in combination with an aluminum sheet (0.2–0.4-mm thick and 99.9% pure) was placed between the X-ray tube and the detector.
- The detector was collimated using lead pinhole collimators to avoid detecting secondary X-ray beams.

B) Measurement of absorbed dose (Fig.2)
- The absorbed doses in the Mix-Dp phantom were measured at depths of 0, 3, 6, 9, and 12 cm from the surface of the phantom by inserting radiophotoluminescent glass dosimeters (GD-302M; Chiyoda Technol, Tokyo, Japan) into the phantom when the bismuth sheet, copper plate, or copper with aluminum sheet was placed at the surface of the phantom.

5. Discussion

- More secondary X-rays were generated when the 0.1-mm-thick copper plate with the aluminum sheet was placed, because the photons of low-energy X-ray beams were not attenuated sufficiently by the 0.1-mm-thick copper plate and they generated secondary X-rays by interaction with the aluminum sheet.
- The photons of low-energy X-ray beams were sufficiently attenuated by the 0.3-mm-thick copper plate and there was no further advantage of adding the aluminum sheet. However, the aluminum sheet efficiently attenuated secondary X-rays generated from the 0.2-mm-thick copper plate.

4. Results

A) Photon energy spectra (Fig.3)
- There was a tendency for more photons of primary X-ray beams to attenuate as the thickness of the copper and aluminum increased.
- The photon energy spectrum in the case of the bismuth sheet was a little bit similar to that of the 0.2-mm-thick copper plate.
- More photons of primary X-ray beams were attenuated in the case of the copper plate with the aluminum sheet compared with only the copper plate; however, this difference was negligible in case of the 0.3-mm-thick copper plate.

B) Absorbed dose (Fig.4)
- The absorbed doses were increased in the case of the 0.1-mm-thick copper plate with the aluminum sheet compared with only the 0.1-mm-thick copper plate.
- The absorbed doses were decreased in the case of the 0.2-mm-thick copper plate with the aluminum sheet compared with only the 0.2-mm-thick copper plate, and were decreased as the thickness of the aluminum sheet increased.
- The differences of absorbed doses were negligible between the 0.3-mm-thick copper plate and the 0.3-mm-thick copper plate with the aluminum sheet.

6. Conclusions

- The photon energy spectrum of a primary X-ray beam in the case of placing a commercially available bismuth sheet is a little bit similar to that of a 0.2-mm-thick copper plate.
- The addition of an aluminum sheet is effective in attenuating secondary X-rays generated from a 0.2-mm-thick copper plate.

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