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Radiation dose and image quality as a function of heavy metal filter combinations for a constant film density in chest radiography (1st report)

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INTRODUCTION

It is commonly known that the spectrum produced by an x-ray tube is a broad " white" spectrum. As for the white spectrum, the low-energy portions of the spectrum have essentially no, or only a slight, chance of reaching the image receptor. Therefore, for most diagnostic radiology, an aluminum filter a few millimeters thick is used to remove the low-energy range of x-ray spectrum

On the other hand, in chest radiography, a combination of copper and aluminum filters has been commonly used to increase the average photon energy and reduce the range of radiation intensity reaching the image receptor.

Several authors have reported that in diagnostic radiology a minimum patient dose or a maximum image quality can be achieved with monoenergetic radiation instead of a broad x-ray spectrum. However, the monoenergetic radiation sources such as gamma sources or quasi-monoenegetic x-ray sources are not sufficient for most diagnostic purposes.

A number of recent studies made it clear that selective (K-edge) filters were more suitable than a combination of copper and aluminum (conventional filter) filters used in chest radiography.

The aim of this study is to investigate the potential clinical usefulness of the metals with higher atomic numbers for chest radiography. We have compared the patient entrance exposure, tube loading, and image contrast gained by the use of such metal filters with those obtained from a conventional copper filter.

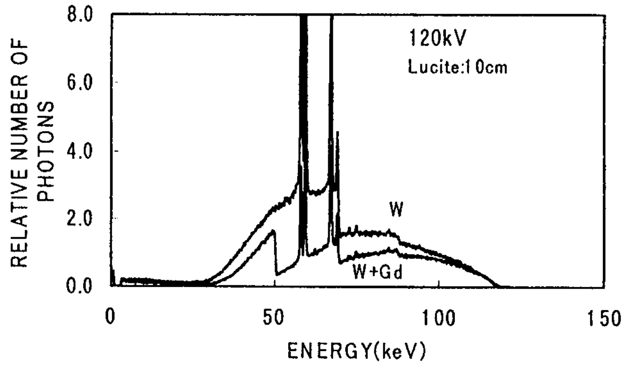
METHOD

Seven heavy metal filters (Barium, Celium, Samarium, Gadolinium, Holonium, Ytterbium, and Tungsten) were used for this study. As for a tungusten filter, two filters different in thickness were used. One is 0.05 thick, and the other 0.10 mm. The other metal filters were respectively combined with a tungsten filter with a thickeness of 0.05mm. Therefore, in total , eight filter combinations were employed as shown in table 1.

Table 1. Added filter materials and their K-edges used in this experiments.

Added filter (W:mm)	K-edge (keV)
Ba+ 0.05W	37.4+69.5
Ce+ 0.05W	40.5+69.5
Sm+0.05W	46.9+69.5
Gd+ 0.05W	50.2+69.5
Ho+ 0.05W	55.3+69.5
Yt+ 0.05W	61.3+69.5
0.05 W	69.5
0.10 W	69.5

Figure 1.Comparison of x-ray spectra obtained with W and W+Gd filters.



In order to investigate the physical properties of heavy metal filters in chest radiography, we simulated the exposure conditions by using the 8-cm lucite phantom. Tube volt was changed from 100 kV to 140 kV with an increment of every 10 kV. To investigate the effect of phosphor material on the patient dose, tube loading, and image contrast, we used three kinds of imaging receptor, namely, $CaWO_4$ (calcium tungsten), Gd_2O_2S:Tb (rare earth), and (BaFBr(I):Eu) (photostimulable phosphor) which are different in K-edge absorption respectively. Patient exposure and tube loading were defined as the ratio of the entrance exposure on the phantom which brings about a net film density of 1.2 by the standard filter (copper 0.1 mm + aluminum 0.5mm), to that by each heavy metal filter.

RESULTS

Figure 1 shows a comparison of x-ray spectra obtained with a tungsten (W) and tungsten+gadolinium (W+Gd) filter, respectively.

Figure 2 shows the dependence of the relative incident exposure on the x-ray tube potential and the various filters used, as proved with a 8-cm-thick Lucite phantom and rare earth screen. A 0.1 mm W filter shows lowest patient exposure reduction ratio (23% -15%) at the range of 100 kV to 140 kV. However, as to each metal filter, entrance exposure ratio decreases as the x-ray tube voltage increases. It was found that the magnitude of patient exposure ratio varied according to each image receptor.

Tube loading increased by 2 to 3.5 times compared with that in the case of a standard filter although this experimental data is not shown here.

DISCUSSION & CONCLUSION

The most important problem for diagnostic radiology is that of obtaining adequate image quality while keeping th the absorbed dose to the patient as low as possible. For this purpose, several authors have suggested the use of heavy metal filters with K-edges in the diagnostic energy range to reduce the width of the x-ray spectrum and hence reduce patient exposure. However, the effect of these filters on the patient exposure and image quality has not been reported in chest radiography. In this study we have investigated the potential clinical usefulness of the metals with higher atomic number for chest radiography.

Our initial experimental results demonstrated that the image receptor with a rare earth screen and photostimulable phosphor was more advantageous in the patient exposure than the receptor with a calcium tungsten screen.

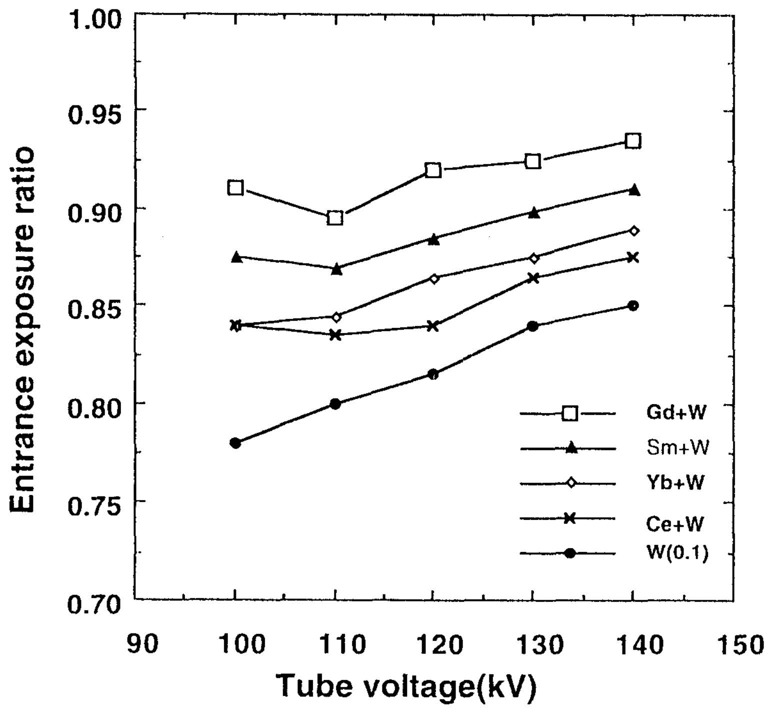


Figure 2. Dependence of the relative entrance exposure on the x-ray tube potential and the various filters. Gd_2O_2S:Tb phosphor material was used as a imaging receptor.