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Effect of scattered x-rays on subject contrast and image sharpness

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Abstract The purpose of this study is to investigate the effect of the scattered x-rays on the subject contrast and image sharpness for various tube voltages. For the purpose, we measured the scatter-to-primary ratio(SPR) for tube voltages of 50 to 100 kV and obtained the tube voltage dependence of the subject contrast of an aluminum plate in a polymethyl methacrylate(PMMA) phantom. Furthermore, the overall modulation transfer functions(MTFs), which consist of MTFs of a screen-film system and scatter MTFs, were obtained for tube voltages of 50 to 100 kV. The subject contrast decreased with the tube voltage due to that the SPR increased with the tube voltage and that the difference in effective linear attenuation coefficients between the object and its surroundings decreased with the tube voltage. The maximum frequency of the overall MTF decreased from about 2 mm^{-1} to 1 mm^{-1} with the tube voltage increasing from 50 to 100 kV.

1. Introduction

The image contrast of the object is determined by film contrast and subject contrast(SC).[1] The subject contrast is commonly defined by :

$$SC = \log_e(\frac{P + \Delta P}{P}) \tag{1}$$

where $P + \Delta P$ is the transmitted energy fluence associated with the object of interest and P is the transmitted energy fluence of its surroundings. Because of the scattered x-rays caused in human body, the subject contrast is reduced as follows:[1]

$$SC \cong \frac{\Delta P}{P}(1 + SPR)^{-1} \tag{2}$$

$$= (e^{\Delta\mu_{eff}t} - 1)SDF, \tag{3}$$

where SPR is the scatter-to-primary ratio, SDF(scatter degradation factor) = $(1+SPR)^{-1}$, $\Delta\mu_{eff}$ is the difference in effective linear attenuation coefficients between the object and its surroundings, and t is the thickness of the object.

In addition, the image sharpness also decreases with the scattered x-rays increasing. The degradation of the image sharpness caused by the scatter x-rays can be evaluated by a scatter MTF which depends on the SPR.[2] Since the SPR varies with the tube voltage, the subject contrast and image sharpness are also dependent on the tube voltage. Our aim of this study is to investigate the effect of the scattered x-rays on the subject contrast and image sharpness for various tube voltages.

2. Methods

The x-ray source was a Shimadzu Circlex 0.6/1.2 P38DE-80 tube coupled to a single-phase generator ED 150L. The tube voltages were set at 50 kV to 100 kV. The polymethyl methacrylate(PMMA) of 20 cm thickness, 30 cm wide and 30 cm long was used as the phantom. An aluminum plate of 1 mm thickness, 10 mm wide and 10 mm long was inserted at a 10 cm depth in the phantom as an imaging task. The source detector distance of 100 cm and the rectangular exposure field of 20 cm × 20 cm were chosen. The detector is a Ge detector or a screen-film system.

Subject contrast. We measured the primary and scatter x-ray spectra by means of a method[3] of Kubota *et al.* using Ge detector(Princeton Gamma-tech, NIGP1013345) and conical collimator. From the integration of the energy spectra, the SPRs were obtained for various tube voltages.

The effective linear attenuation coefficients of the aluminum and PMMA were determined from photon mass attenuation coefficients[4] for the effective energy of the x-rays incident on the phantom. Figure 1 shows the tube voltage dependence of the SPR and difference in effective linear attenuation coefficients. By substituting these results into equation (3), the tube voltage dependence of the subject contrast was obtained.

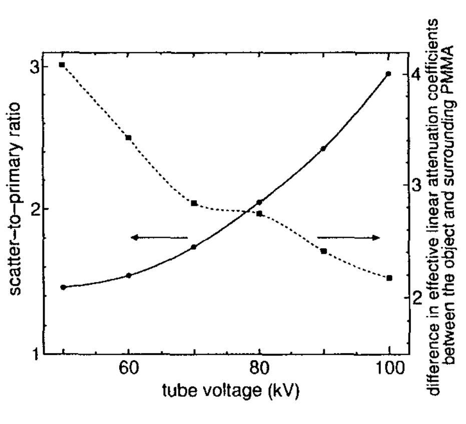

Fig. 1: Tube voltage dependence of the SPR and difference in effective linear attenuation coefficients.

Overall modulation transfer function. The Quanta III/HR-S 30 system was used as an imaging detector. The radiographs of the phantom including the aluminum plate were taken at a density consistent with the maximum gradient of the film. The edge responses of the aluminum plate were traced by using a Konica PDM-7B microdensitometer. The scanning aperture and the sampling interval were 10 μm and 10 μm × 1000 μm. The edge response in specular density were converted into those in exposure. They were differentiated and Fourier transformed. The results are the overall modulation transfer functions(MTFs).

The overall MTF consists of an MTF of a screen-film system and a scatter MTF.

3. Results and Discussion

The tube voltage dependence of the subject contrast is shown in Fig. 2. The subject contrast decreases with the tube voltage. One reason is that the scattered x-rays increase with the tube voltage as shown in Fig. 1. The other reason is that because the average photon energy becomes higher with the tube voltage increasing, the difference in effective linear attenuation coefficients between the object and its surroundings decreases with the tube voltage as shown in Fig. 1.

The results of the overall MTFs for the tube voltages of 50 kV to 100 kV were shown in Fig. 3. The maximum frequency of the overall MTF decreases with the tube voltage. In particular, the frequency for 100 kV is about 1 mm^{-1}. The reason is that the number of the Compton scattered x-rays increase with the tube voltage. However, maximum frequency of the overall MTF is about 2 mm^{-1} even for 50 kV. This reason is that the scatter angles of the Compton scattered x-rays with lower energies are greater.

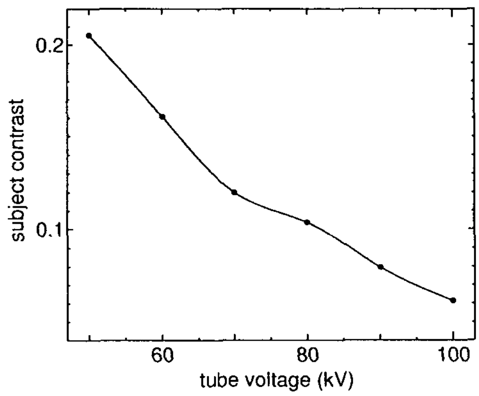

Fig. 2: Tube voltage dependence of the subject contrast.

4. Conclusions

We investigated the effect of the scattered x-rays on the subject contrast and image sharpness for various tube voltages.

The subject contrast decreased with the tube voltage due to that the scattered x-rays increased with the tube voltage and that the difference in effective linear attenuation coefficients between the object and the its surroundings decreased with the tube voltage.

The maximum frequency of the overall MTF decreased from about 2 mm^{-1} to 1 mm^{-1} with the tube voltage increasing for 50 to 100 kV.

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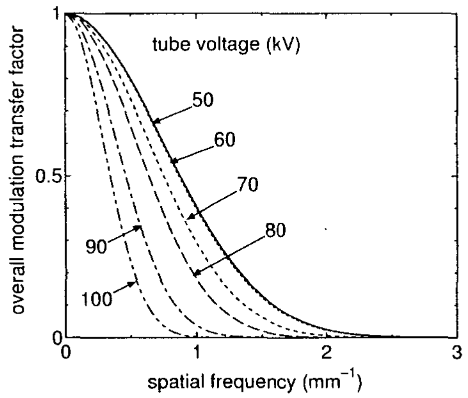

Fig. 3: Overall modulation transfer functions for various tube voltages.

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