

Dosimetric techniques for mammography X-ray beams

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1. Methodology

The materials used in this work were PTW Diados ionisation chamber and electrometer, SIB mammography breast substitute phantom, AGFA Mamoray screen and film types, X-Rite densitometer and AGFA Imaging Min/Med film processor with processing cycle and temperature of 90 s and 34.5°C, respectively. For the incident air kerma method, mean glandular dose (MGD) values were determined from the tube loading (TL) and the entrance surface air kerma (ESAK) measurements, following the procedure described by the European Commission (CEC, 1996). Each electrometer reading was corrected for ambient temperature and pressure (Assiamah et al., 2003a). The half value layer (HVL) for the selected TL was determined and the MGD calculated using the equation

$$\text{MGD} = \text{ESAK} \times g \times p, \quad (1)$$

where g is the ESAK to MGD conversion factor at the measured HVL and the p -factor converts ESAK for the PMMA breast substitute to that of the model breast (Dance et al., 1999). In calculating MGD from spectral energy fluence, X-ray spectra measurements using the high-purity germanium detection system and correction techniques, as described in a companion paper (Mavunda et al., 2003), were used. Each of the spectra was modified to take into account the presence of the breast compression plate and also the aluminium thickness needed to match the first HVL obtained there to that from the ionisation chamber measurement for the same TL. Exposure, $X_i(E)_{T,P,H}$ (in roentgen), was calculated

from the adjusted photon fluence, $\phi_{i(\text{corr})}$ from

$$X_i(E)_{T,P,H} = \frac{1.83 \times 10^{-11} \phi_{i(\text{corr})} E_i (\mu_{\text{en}})_i^{\text{air}}}{\rho_{T,P,H}}. \quad (2)$$

Where E_i is photon energy of the i^{th} energy bin; $(\mu_{\text{en}})_i^{\text{air}}$ is the linear energy absorption coefficient of air at s.t.p.; $\rho_{T,P,H}$ is the density of air at temperature T , pressure P and humidity H (Cember, 1996). Absorption energy coefficient “spectra” of $(\mu_{\text{en}})_i^{\text{air}}$ were generated for each energy bin (Assiamah et al., 2003b). Using exposure to MGD conversion factor of 0.873, the MGD was calculated (Wolbarst, 1993) from the exposure values by

$$\text{MGD} = 0.873 X_i(E)_{T,P,H} \times g \times p. \quad (3)$$

2. Results and discussion

The ESAK and MGD values (Table 1) from both techniques showed slight differences (less than 5–12%) for the thinner phantom thicknesses and lower kVp values. At 32 kVp however, the ESAK and MGD from the spectral measurements differed by as much as 100% from the direct measurements, even though they have the same first HVL. The significant difference in the ESAK and MGD values from the direct measurement and that from the spectral data was ascribed to the larger component of scattered radiation incident on the germanium detector. For the same phantom thickness, there was dose reduction in using higher kVp values than lower ones. The reduction was significant and dependent on phantom thicknesses. Fig. 1 shows the film contrast at 28 kVp with varying tube loading for different PMMA phantom thicknesses for a range of optical densities measured using the procedure by Desponds et al. (1994). The contrast versus phantom thickness relationship was linear for thinner phantoms and exponential for larger ones.

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Table 1

Comparison of ESAK and MGD calculated from measured air kerma values with that calculated from measured spectra at focal spot detector distance of 65 cm

Nominal tube voltage (kV _p)	Phantom thickness (mm)	Direct measurements		Measured spectra	
		ESAK (mGy)	MGD (mGy)	ESAK (mGy)	MGD (mGy)
26	20	1.16	0.52	1.18	0.53
26	30	2.94	0.93	2.6	0.81
28	30	2.51	0.85	2.64	0.89
26	40	6.02	1.45	6.2	1.48
28	40	5.23	1.35	5.5	1.35
30	50	8.3	1.8	8.0	1.72
32	50	6.41	1.44	12.9	2.8
32	60	13.41	2.62	25.8	5.0

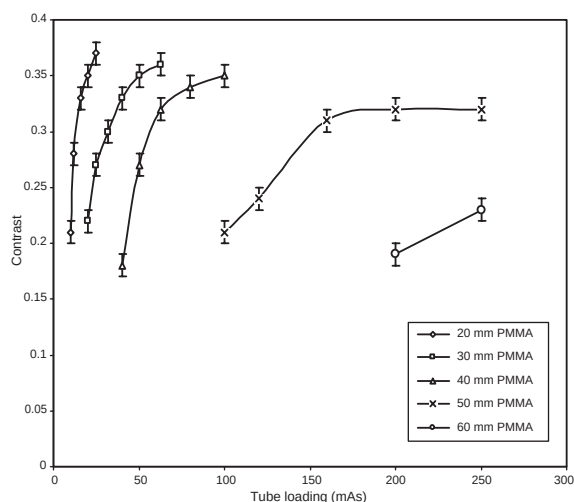


Fig. 1. Variation of contrast with TL for different thicknesses of PMMA phantom at a tube voltage of 28 kV_p.

The contrast of the 60 mm phantom was low and assumed to be due to reciprocity law failure. (NB to generate a stable, latent image sensitivity speck a grain of silver halide must accumulate a “critical mass” of silver atoms. If exposure rate is too low, i.e. long exposure times and therefore low flux, some silver atoms could be freed and leak away from the sensitivity speck resulting in criticality not achieved. This behaviour is referred to as reciprocity law failure. In the case of mammography for a given tube voltage and current, films become lighter as a result of long exposure times (Wolbarst, 1993).)

The study has shown that the incident air kerma method and spectral energy fluence method can be used

to estimate MGD values. However, at higher Mo anode X-ray tube voltages the spectral measurement method is significantly more sensitive to the presence of scatter radiation. The best range of optical density was 0.9–2.0 for thinner phantoms with equivalent contrast values of 0.25–0.38 and for the thicker phantoms, a range of 0.8–1.6 with equivalent contrast values of 0.2–0.34.

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