BONE MARROW AND THYROID ABSORBED DOSES FROM MAMMOGRAPHY

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INTRODUCTION

Breast dose from mammography has been estimated by various investigators, because of the established effectiveness of mammography in early screening for breast cancer and the relatively high sensitivity of the breast to radiation carcinogenesis (1,2). Nevertheless, to our knowledge, there is no available information in the literature about absorbed doses from mammography to organs other than the breast. The absorbed doses to the red bone marrow in the sternum and to the thyroid, due to scattered radiation from mammographic examinations, have been measured using a plexiglas upper-body phantom and thermoluminescent dosemeters. Their dependence on several parameters has also been examined.

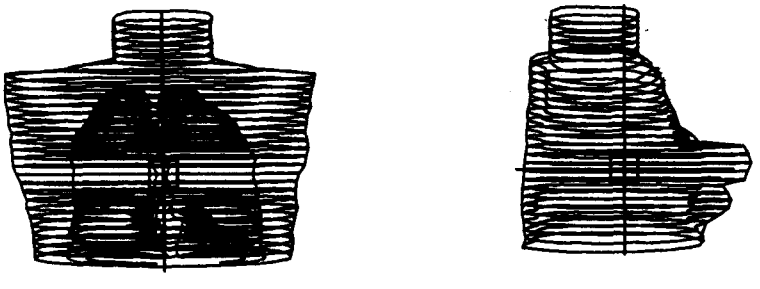
It is necessary to emphasise that this work is still in progress.

MATERIALS AND METHODS

A plexiglas upper-body phantom (figure 1) was used to simulate the female body. The phantom consisted of 30 slices, 1 cm thick, and it simulated the contour of a standard size female upper body. A spongy material inside the phantom simulated the lungs. The compressed breast was simulated by breast-shaped plexiglas slices of various sizes and thicknesses, its midline always aligned with a specific slice. Small holes capable to accommodate thermoluminescent (TL) dosemeters were drilled on each slice of the phantom. The locations of the holes were properly selected to correspond to the following organs inside the body: bone marrow in sternum, thyroid, oesophagus, left and right lung, stomach, colon and liver. In this paper measurements of the doses to the bone marrow and the thyroid are presented.

The dose measurements were performed using two LiF based TLD systems, namely TLD-100 (LiF : Mg, Ti) and GR-200 (LiF : Mg, Cu, P), on 10 sites into the phantom selected to cover the bone marrow in sternum and on 5 sites covering the thyroid.

The TL measurements were performed with a TL analyser Type 711 of the Littlemore Co. The glow-oven was first evacuated at 10^{-2} Torr and N_2 of high purity was left to flow during the readout. The heating rate was 2°C/sec. The light emission was detected by an EMI 9635 QA photomultiplier tube and the glow curves were stored in a computer via a 1024-channel ADC card operating in the MCS mode for further data analysis.



a. b.

Figure 1. The plexiglas upper body female phantom used in the present work.
a. Frontal view
b. Lateral view

Prior to any use the dosemeters were annealed; the TLD-100 at 400°C for 1 hour and at 100°C for 2 hours, whereas the GR-200 at 240°C for 10 min. Before the measurements all the dosemeters were post-irradiation annealed at 80°C for 1 hour. The crystals of both TLD-100 and GR-200 were grouped in terms of sensitivity within 2.5%.

The TL dosemeters were calibrated in beam, against a 10X5-6M ion chamber suitable for measurements in mammography, connected to a Radcal 9015 Monitor.

Most measurements were performed with GR-200 since they are much more sensitive than TLD-100 (at the energies involved by a factor of about 20).

The irradiations were performed on a IMS Giotto Mammography H.F. x-ray unit with a Mo/Mo anode-filter combination and source to image distance 60cm. A thorough quality control of the mammographic unit and the automatic film processor was done prior to the measurements with the phantom. The accuracy and reproducibility of all the exposure parameters (such as kVp, mAs, radiation output) and the automatic exposure control (AEC) system were tested and verified. The performance of the film processor was evaluated by sensitometry.

Measurements were repeated at several irradiation conditions as well as with different plexiglas thicknesses. The high voltage ranged from 26 to 32 kVp and the breast shaped plexiglas thicknesses were 2, 4.5 and 6 cm. These thicknesses correspond to 2.3, 4.9 and 6.4 cm of breast tissue, having a composition of equal parts by weight adipose and glandular tissue (3).

RESULTS AND DISCUSSION

Doses to the bone marrow in sternum and the thyroid at 10 and 5 different sites respectively inside the phantom were measured for three combinations of kVp and plexiglas thickness routinely used in mammography, namely 26 kVp - 2 cm, 28 kVp - 4.5 cm and 30 kVp - 6 cm. Table 1 presents the mean doses to the bone marrow and the thyroid in μGy/mAs and as a percentage of the corresponding entrance dose. These mean values were calculated by merely averaging the corresponding measurements at the different sites.

A general increase of the dose can be observed across the table as kVp, mAs and thickness increase.

Table 1. Mean doses to the bone marrow and the thyroid

	26 kVp, 12 mAs 2 cm plexiglas craniocaudal view		28 kVp, 32 mAs 4.5 cm plexiglas craniocaudal view		30 kVp, 64 mAs 6 cm plexiglas craniocaudal view	
Entrance dose	1197 ± 21 μGy		4550 ± 32 μGy		11934 ± 41 μGy	
	μGy/mAs	% entrance dose	μGy/mAs	% entrance dose	μGy/mAs	% entrance dose
bone marrow	0.40	0.40	0.79	0.56	1.27	0.68
thyroid	0.22	0.22	0.35	0.25	0.51	0.27

The doses measured were generally low, therefore it was decided to restrict further measurements at selected sites only, in order to avoid a prohibitive bulk of measurements. Three sites, namely BMmin, BMmax and BMmid, were chosen for the bone marrow, representing respectively the minimum dose, the maximum dose and the dose to the slice at which the breast shaped plexiglas was centred. One site, TH, was selected to represent the maximum dose to the thyroid.

The dependence of the doses on the mAs and the kVp was then examined separately. The first series of irradiations were performed at 28 kVp with 4.5 cm plexiglas at 24, 28 and 32 mAs (Table 2). These parameters resulted in mammograms with optical densities between 1.2 and 1.55. It was found that the dose rises linearly with the mAs, as it was expected. Therefore, these measurements provide some good evidence on the accuracy of our results, since the ratio dose/mAs remained constant.

Table 2. Dependence of the dose to the bone marrow and to the thyroid on the mAs

	24 mAs		28 mAs		32 mAs	
Optical density	1.21		1.40		1.55	
	μGy	μGy/mAs	μGy	μGy/mAs	μGy	μGy/mAs
BMmin	15.4 ± 1.6	0.64	18.5 ± 2.0	0.66	20.2 ± 1.8	0.63
BMmax	32.2 ± 2.7	1.34	38.9 ± 3.5	1.39	43.6 ± 3.9	1.36
TH	12.4 ± 0.9	0.52	14.6 ± 1.1	0.52	15.9 ± 1.1	0.50

The dependence of the dose to the bone marrow on the kVp was examined by a second series of irradiations which were performed at 32 mAs, with 4.5 cm plexiglas, at 26, 28, 30 and 32 kVp (Table 3). The dose again rises with kVp, being 2.5 to 3 times higher at 32 kVp compared to 26 kVp.

Table 3. Dependence of the dose to the bone marrow on the kVp

	Absorbed dose (μGy)			
Site	26 kVp	28 kVp	30 kVp	32 kVp
BMmid	23.5 ± 3.1	30.4 ± 5.2	46.6 ± 9.9	54.0 ± 12.3
BMmax	27.5 ± 3.8	38.2 ± 6.8	48.5 ± 10.1	78.5 ± 15.2

The maximum dose to the bone marrow and the thyroid after a complete breast screening examination was finally evaluated. A typical screening examination consists of two craniocaudal and two mediolateral views, one for each breast. In order for our results to be meaningful, the irradiation parameters were properly selected to closely match those of a typical examination for the x-ray system used, i.e. 26 kVp, 12 mAs for a plexiglas thickness of 2 cm, 28 kVp, 32 mAs for a plexiglas thickness of 4.5 cm and 30 kVp, 64 mAs for a plexiglas thickness of 6 cm. These conditions result in mammogram with optical densities of 1.2 to 1.6, which is the range normally required in a typical examination (Table 4).

Table 4. Total examination dose (two craniocaudal and two mediolateral views)

	Absorbed dose (μGy)		
Site	26 kVp, 12 mAs/view 2 cm plexiglas	28 kVp, 32 mAs/view 4.5 cm plexiglas	30 kVp, 64 mAs/view 6 cm plexiglas
BMmin	14.5 ± 2.5	55.2 ± 5.2	129 ± 25
BMmid	20.3 ± 3.2	93.9 ± 7.5	199 ± 54
BMmax	26.4 ± 3.5	155 ± 20	337 ± 95
TH	10.6 ± 2.1	40.3 ± 6.2	100 ± 28

Table 4 shows that the maximum measured doses to the bone marrow and the thyroid ranged from 25 to 340 μGy and from 10 to 100 μGy respectively, for a complete examination (four views), depending on breast thickness.

CONCLUSIONS

The absorbed doses to the red bone marrow in the sternum and to the thyroid due to mammographic examinations were measured and their dependence on several irradiation parameters was examined. It was found that the doses depend strongly on the kVp and rise linearly with the mAs. The measured doses for a complete screening examination were found to be generally low. However the dose to the bone marrow can become significant for large breast thicknesses.

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