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ABSORBED DOSE DISTRIBUTIONS USING THE ISODENSITOMETRIC METHOD FOR EXPOSURES WITH FILTER EMPLOYED FOR MAMMOGRAPHIES

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Abstract. This paper presents the 2D, 3D absorbed dose distributions and isodose distributions obtained by the isodensitometric method for the determination of radiation field characteristics used together with sundries filters, in mammography. Thus the next filters: Cu (copper), Al (aluminum) and Th (thorium), with different thicknesses and having the role to attenuate the high energy photons were used. To obtain the dose distributions, the film densitometer from MULTIDATA System – USA, outfitted with RTD4 software – 5.2 version, was used. Future experiments will include mammography investigations showing malign and benign tumors, and having blackening density values and tumor volume penumbra, will be made differentiations between both types of above mentioned tumors.

Key words: Isodensitometric method, absorbed dose distribution, film densitometer.

1. INTRODUCTION

Because the breast cancer is among the most frequently met and represents near non-feminization stigma about breast amputation, an important mortality cause at women (very seldom present to men) are due to population screenings in which the investigations were made by mammography. Unfortunately, the results were not positive and indeed the method was criticized on the grounds of the increasing oncogenetically risk by exposure to radiations. Beam characteristics, dose distribution uniformity in the investigated volume, the satisfaction of ALARA principle in this diagnose effort represent the essential technical conditions to clear out the negative false or positive false possible results and to minimize the risk of developing a new breast neoplasm.

Radiographic film was one of the first used in natural radioactivity detection (1896, Becquerel discover the natural radioactivity [1]), due to the traceable effect produced on photographic film. Typical radiographic film consists of a radiation sensitive emulsion coated on a transparent polyester base. The emulsion consists of silver halide crystals typically 95% silver bromide and 5% silver iodide suspended in gelatin, in case of Kodak XTL and XV films. The specific emulsion composition and manufacturing process vary with the manufacturer and is often a closely guarded industrial secret. When the emulsion is exposed to ionizing radiation, ionization takes place in the silver halide crystals that result in the formation of a latent image. The relative composition of iodine, bromine and some traces of chlorine yield the unique characteristics of the film sensitivity [2].

The photographic measurement method employed in radiation dosimetry shows the following advantages: permanent measurements record, simultaneous record of different radiations types, good spatial distribution and usage of small sized and weight dosimeters. One of the advantages to use films, for 2D and 3D dose distributions, is the fast determination of them. The film can be placed in different radiation fields and it permits the simultaneous data acquisition from a large area. Another advantage is that only short time irradiations and small doses are required. The radiographic films are an excellent practical tool in medical domain for the relative measurement of dose distribution. It is particularly convenient for determining the central-axis depth-dose and isodose distributions of irregular fields [3].

This paper presents the absorbed dose distributions obtained with the isodensitimetric method, for the determination of external irradiation field parameter used in mammography. The exposed and investigated films are similar to the film used in mammography. The irradiation doses used were 12.27 mSv and 8.04 mSv given by the X-ray generator, from Bucharest Coltea Hospital. The dose values were established from the switchboard, by the medical physicist. The dose distributions were obtained using a MULTIDATA System film densitometer, 9721 model. It can be used to obtain the calibration curve specific to a particular film [4]. In this manner 2D, 3D dose and isodose distributions were obtained corresponding to the investigated films, using different material and thickness.

2. MATERIALS AND METHODS

The films used in the experimental part of the work were Kodak films employed in mammography. The optical densities (OD) of the film were measured using the film densitometer delivered by MULTIDATA Systems – USA.

Film densitometer is used for all standard x-ray films (up to: 45 cm x 50 cm). The film can be of any desired shape, since it is supported on a stationary film table unobstructed by the scanning head.

Film densitometer shown in Fig. 1, is connected by an electrometer to a notebook, where the 2D, 3D dose distributions and isodose distributions corresponding to investigated films can be visualized. The dose distributions are equivalent with blackening distributions registered on films.

Fig. 1 – The film densitometer – 9721 model (from MULTIDATA System).

Film densitometer used for obtaining experimental data is an accurate dosimetry system peripheral device for the measurement of the relative density / dose information that has been captured by standard size X-ray film exposed above to ionizing radiation. As a light source, the system uses special highly efficient light emitting diodes and color compensated solid state detectors, making the device insensitive to ambient light. The light source/detector assembly is driven in finite incremental steps with a 1/16 millimeter resolution over the entire scanning area to ensure precise positioning with a high degree of repeatability and a measurement uncertainty equal with 3.1 % – calculated for a calibration curve [5], of a medical film, obtained with the film densitometer from MULTIDATA.

a) **b)** **c)**

Fig. 2 – Experimentally used films: a) the irradiated film with Al filter; b) the irradiated film with Cu filter; c) the irradiated film with Th filter.

Experimental data presented in this work were obtained using medical films employed in mammography, having a good contrast needed for a good visualization of the optical densities obtained.

In experiments the used film dimensions were (18 cm × 24 cm). The films presented in Fig. 2 were introduced in a lead box and in the box slot (10 cm × 15 cm) Al, Cu and Th filters were placed. Irradiations were made with a perpendicular beam on the filter surface. In this paper was evaluated the homogenity of the mass density of the filters. In practice, the filters structure must be homogeneous, to assure the uniform exposure of the patient breast. The role of the different filter used in mammography is to suppress the photons at greater energies, for example a molybdenum filter by 0.3 mm is used to suppress the photons with energies greater than 20 keV and a large number of low-energy photons are used in recording the images [6].

Table 1

The irradiation condition proper to investigated films

Film	a)	b)	c)
Filter type	Al	Cu	Th
Filter thickness (mm)	0,4	1	4
X ray dose (mSv)	12.27	12.27	8.04
Voltage (kV)	120	200	200
Current (mA)	15	15	15
Exposed surface of the film (cm^2)	10 × 15	10 ×15	10 ×15

Table 1 shows the irradiation conditions proper for the medical films used in experiments.

3. ISODENSITOMETRIC METHOD USED FOR THE DOSE DISTRIBUTION DETERMINATION

A film detector is defined by its "dose-response curve" - the Optical Density (OD) of an exposed film versus absorbed dose [7]. The film densitometer characteristic curve is given by the relation between the measured values of the absorbed dose and optical density from the film.

The Optical Density is defined as (1) [8]:

$$\mathrm{OD} = \log_{10}(I_0/I) \text{ or } \mathrm{OD} = \log_{10}T, \tag{1}$$

where I and I_0 are the light intensities in the densitometer with and without the film and T is the transmittance.

The transmittance is related by (2) [8]:

$$T = e^{an}, \quad (2)$$

where a is the average area / grain, n is the number of developed grains/cm^2.

Next one can write the relation (3) [8].

$$\text{OD} = \log(\text{T}) = an \log_{10}\text{e} = 0.4343\ an. \quad (3)$$

Knowing that: $n / N = a\Phi$, where N is the grains number / cm^2 and Φ is the electron fluence, the second equation becomes (4) [8].

$$\text{OD} = 0.4343\ a^2 N \Phi. \quad (4)$$

For a irradiated film, the corresponding percent of the optical density having the bigger blackening, corresponds to the maximum dose used for irradiation, and the point where the value of the optical density is equal with half of the maximum optical density percent, the absorbed dose on film have the value equal with half of the maximum dose used.

The use of film dosimetry to measure dose distribution should be restricted to situations where the influence of the possible energy spectrum changes is not significant [9].

4. RESULTS AND DISCUSSIONS

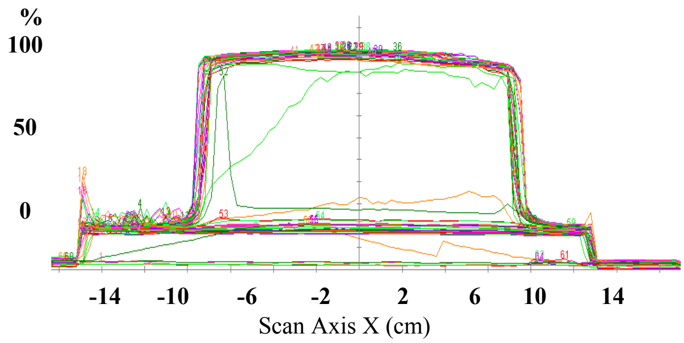
Fig. 3 shows the 2D dose distributions for films placed to conduct measurements in a), b) and c) conditions presented in Table 1.

The lines near 0 percent from a), b) and c) distributions in Fig. 3, are given by the areas where the scanner was scanning the transparent table of the film densitometer, on which the films were placed. Next, the lines near 50 percent are given by the non-irradiated film areas.

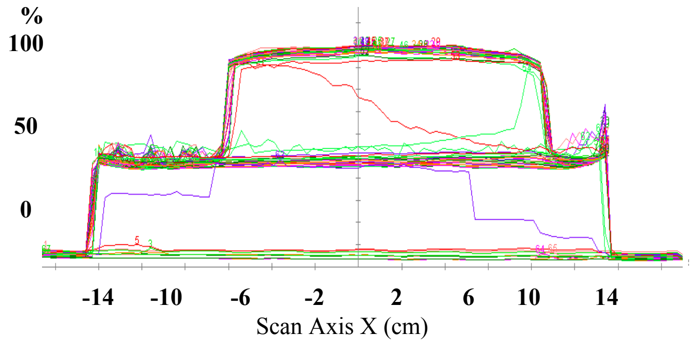
In the left side of the dose distributions, the existent variations are given by the film areas where the radiologist wrote, by a black marker, some irradiation conditions. The film area with the biggest densities correspond to a maximum percentage (100 %) and it is given by the radiations arrived to the film after their passing through the used filters.

Next, using RTD 4 software delivered with the film densitometer, the isodose distributions for the investigated films are presented.

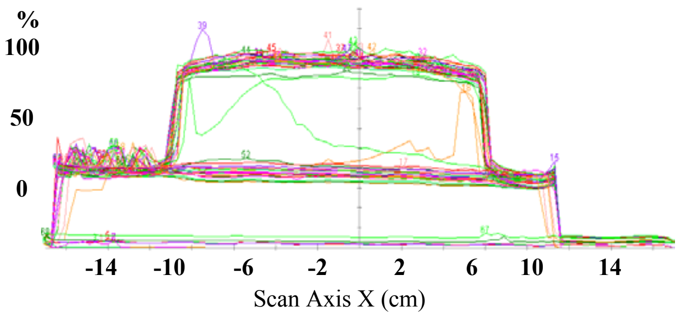
Fig. 4 presents the isodose distributions, where the maximum optical densities percentage from the figures, correspond to the areas in which the films were irradiated between the lead box slot with the filters placed in a), b) and c) conditions from Table 1.



a)

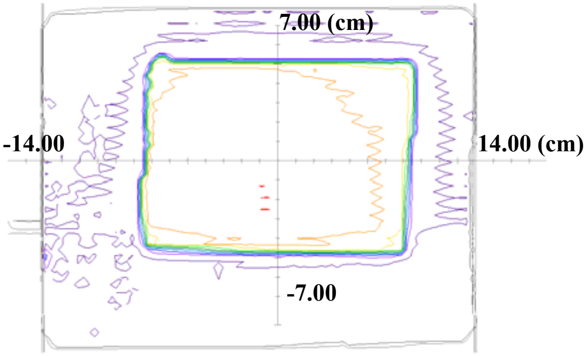


b)

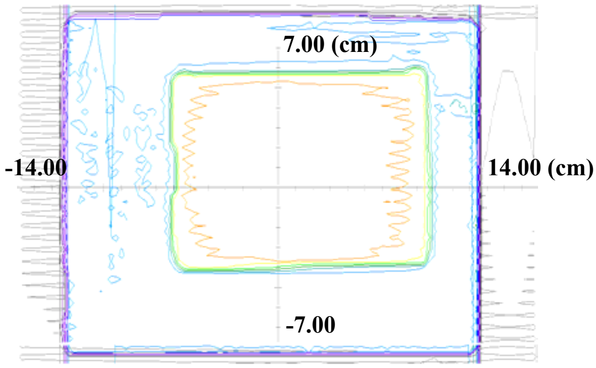


c)

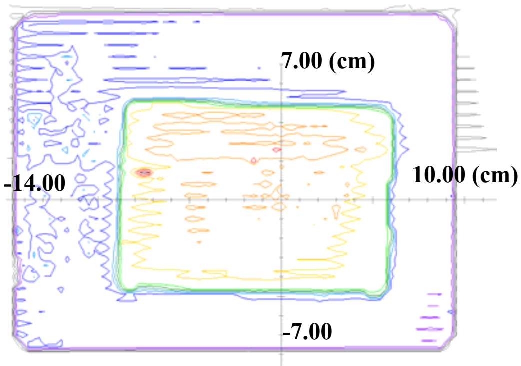
Fig. 3 – 2D dose distributions for irradiated films: a), b) and c).



a)



b)



c)

Fig. 4 – Isodose distributions for irradiated films: a), b) and c).

The central areas from the a), b) and c) images of the Fig. 4, corresponds to the biggest blackening on the film and the next lines (beginning from the center of the figure to the exterior) are given by the next blackening areas on the films, with much lower blackening distributions.

Analyzing the 2 D dose distributions one can see that the mass density of the Th filter is not homogeneous, that's mean it have not the same mass density on the entire surface. Fig. 5 shows the 3D dose distributions that are equivalent to the blackening distributions from the investigated films a), b) and c) from Fig. 2, made with RTD4 software.

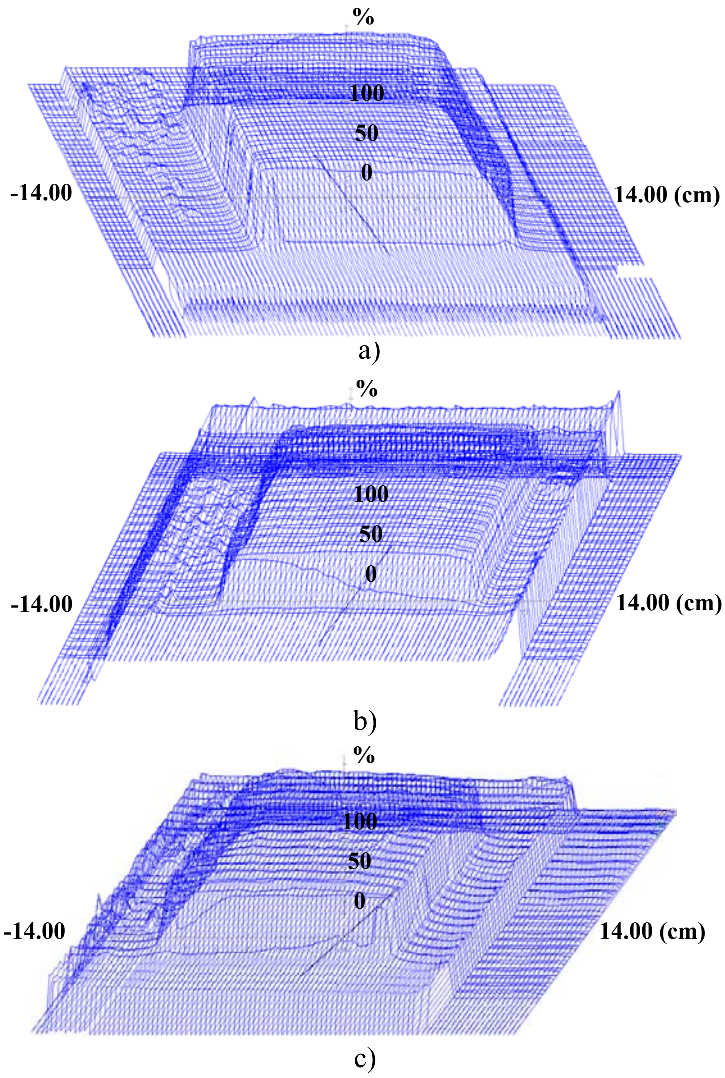


Fig. 5 – 3D dose distributions for irradiated films in conditions a), b) and c).

Images from Fig. 5, present the 3D dose distributions, recorded using the same film densitometer and RTD4 software like in Figs. 3 and 4. The areas with the blackening densities of 0 percents, correspond to the glass table of the film densitometer (were the film was placed), scanned by the light source / detector assembly. The next “step” percent presented corresponding to the film areas irradiated, developed but shielded by the lead box and the higher percent areas correspond to the film areas (10×15 cm^2) irradiated through the filters and developed.

Comparing Figs. 3, 4 and 5, we can conclude that isodose distributions from Fig. 4 show which filters can be used in mammography, having good mass densities, namely, Al and Cu filters.

The third filter (Th) can’t be used in mammography because of its non-uniform mass density, as seen more explicit in Fig. 4, c). The non-uniform mass density of the Th filter can be done by the manufacturing defect of the foil material.

5. CONCLUSIONS

This paper presents the isodensitometric method using the film densitometer from MULTIDATA System-USA, outfitted with RTD 4 software.

2D dose distributions, 3D dose distributions and isodose distributions were made on irradiated medical films, using Al, Cu and Th filters, from the Clinical Hospital „Coltea” from Bucharest, using RTD 4 software – 5.2 version.

The major conclusion reffers to filter used in mammographies and consists in the fact that the filters must have homogen mass densities, to assure the uniform exposure of the patient breast.

In our study was evidenced that the Th filter can’t be used in mammographies due to it non-homogen mass densities, demonstrated by film densitometer scanning.

The use of this method need future investigations in order to diferentiate the malign and benign tumors by comparing: the blackening density values recorded on medical films and the tumoral volume penumbras, that will eliminate the necesity of biopsies, a method having sometimes bad results to the patient.

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