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Physical method for the diagnose and therapy of mammary and bone tumors using film densitometry

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This work refers to the tumoral formations within breast and pelvis area, based on mammography and lumbar area radiography. The paper also presents the experimental results obtained by using the film densitometer, delivered by MULTIDATA Systems – USA for bleackening densities determination appeared on radiographic films, for some tissues showing tumoral formations. As a result of scanning with the film densitometer, 2D and 3D bleackening densities distributions are represented as bleackening isodensities distributions which are equivalent to the isodose distributions recorded on radiographic films.

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1. Introduction

The employed film densitometer is an accurate dosimetric system, used as a peripheral device for measuring information about relative density/dose, obtained on a film previously exposed to ionizing radiations. The system use special diodes, as light source which make-up a balanced circuit, making the device insensitive to ambient light or to other environment changes. The source-detector lighting assembly is operated in finite 1/16 mm steps, along the total scanning surface to assure an accurate positioning with a high degree repetition.

For obtaining the "quantitative" experimental results, radiographic films (mammography, radiography in lumbar area) obtained at "Prof. Dr. Al. Trestioreanu" Oncologic Institute Bucharest were used. Based on the blackening distributions, obtained after the radiographies scanning using the film densitometer, the tumoral formations on the radiological films can be precisely located, accurately confined, and the tumor dimensions from the perpendicular plane on the irradiation beam plane can be precisely determined. Having this information, the radiotherapy planning can be made, such as the irradiation moment of the tumor, the healthy tissue in its vicinity being as much as possible protected by ionizing radiation action.

The work starts with a short presentation of the dosimetric method principle and of the optical density (OD) concept, followed by dose distribution description of the tumor formation, a presentation of physical scanning method, the determination of the irradiation target and treatment planning, finalized with the results, discussion and conclusions of this work.

2. Materials and methods

2.1 Method principle

The photographic film was used first in natural radiation detection, traceable effect produced on photographic film - Bequerel (1896). Radiation-sensitive photographic emulsion is a convenient environment for dosimetric measurements since its characteristics, sensitivity in particular, may be controlled by composition and its preparation process wide-limits and it can also be adapted to different type radiation measuring. It is known that ionizing radiation effect is the blackening of photographic emulsion, meaning a film dose radiation measuring. The emulsion sensitive component is a silver halide, the used one being AgBr (silver bromide).

The emulsion consists of silver halide crystals whose dimensions vary about the average of 0.5 to few μm in diameter, embedded in gelatin, coated on both sides by transparent plastic sheet, called the film base. The dimension of crystals is important for the emulsion sensitivity. The photographic measurement method employed in radiation dosimetry shows the following advantages: permanent measurements record, simultaneous record of different radiations types, repeated reading of the same film, large area dosimetry especially

for electron beams, linearity of dose (over a short dose range, OD can be treated linearity with the dose for most films), dose rate independence permanent record, good spatial distribution of dose or energy permitting realization of little detectors.

A film densitometer is defined by the "response curve" [1] - the OD versus dose curve for an x-ray exposed film.

The film densitometer characteristic curve is the relation between the measured values and film OD. The OD (1) is defined as:

$$OD = \log_{10}(I_o/I) \text{ or, } OD = \log_{10}(1/T) \quad (1)$$

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 the second equation:

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

where *a* is the average aria/grain, n is the number of developed grains/cm^2 and N is the grains number/cm^2.

Knowing that $n/N = a/\Phi$, where Φ is the electron fluency, the second equation becomes:

$$OD = an \log_{10}e = 0.4343\ an = 0.4343\ a^2N\Phi \quad (3)$$

Therefore**,** OD is given by electron fluency Φ, number of grains *N*, and the grain average aria *a*.

Based on relation (3), the most of film detectors are operating.

2.2 Dose distributions for tumor formations

The clinical radiographical films obtained for different locations in the human body, can be investigated in more ways, e. g., use of negatoscope. In the case of physical method used in this work, the radiographic films are investigated with the film densitometer. The densitometer is reading the information related to blackening densities from films, using the detector-light source assembly.

The obtained information are next represented in 2D, 3D blackening distributions, blackening isodensities respectively, which are equivalent to the radiation dose reaching the dosimetric film. After the radiation dose passing through the tissue having a low density (lung), the radiations, reach to the film in a large quantity, than in the case in which after passing through the tissue with having a high density (bone tissue), because the most of radiation dose is stored in the respective tissue. The literature [2] specifies that mammary tissue, with a big density of colagen, are succeptible to the cancer tumor accurence followed by metastatsis. On the mammography, the area in which the tumor is located, has a lower bleackening density than in the healthy mammary tissue, because the mass density of tumoral formation is larger than the healthy tissue area, and a big part of the radiation rests in the tumor. Using 2D, 3D bleackening distributions and bleackening isodensities coresponding to a mammography, the tumor dimension and localization can be determinated.

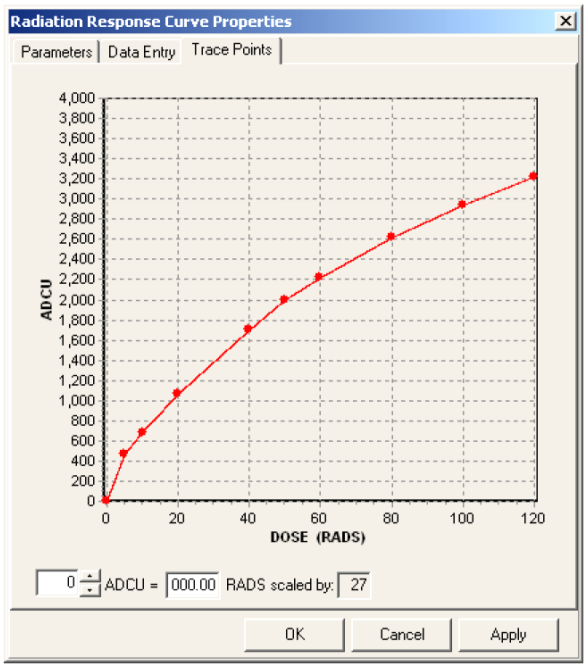
2.3 Physical scanning method

The film densitometer system is a device specially used for the determination of radiological film bleackening density, after a radiation exposure. Because the radiation image on film is a white-black one with different bleackening densities, the device can be used as a base for a printer or a device with the same function. For the film densitometer, radiographical films no bigger than 14 inch x 17 inch (36 cm x 45 cm) are used. The film can have any shape and dimension, as long as it doesn't override the reading area of the scanning head. The source-detector assembly can be programmed to move in finite steps with 1/16 mm resolution, on all the scanning surface to assure any accurate positioning with a high degree repetability.

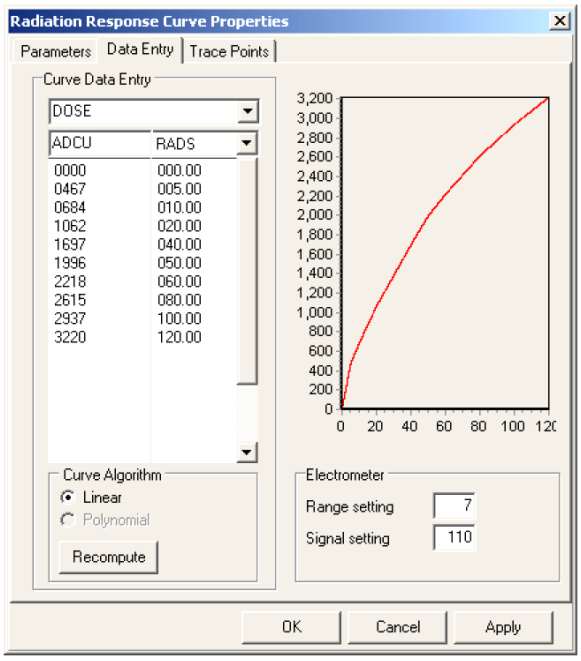
The general specification for this system are: scanning aria films is up to 37 x 45,5 cm inclusively; scanning speed slowing rate is 5 cm/sec maximum on each axis; sampling resolution has a mechanical 0.25 mm (1/4 mm) increment and an electronic one 0.0625 mm (1/16 mm) over the entire scanning area to ensure precise positioning with a high degree of repeatability; detector driving mechanism consists of pulse driven stepping motors with the power transmission via a stainless steel cable over driving pulleys; absolute positioning repeatability is 0.5 mm, on long term and after warming up it is 0.1mm or better; OD Units (maximum) and output signal is 2.5 Volts/OD units; sensitivity ranges come from Software controlled range selection from 0 to 4 and 0 to 2 OD, corresponding to a full scale output of 10 Volts; densitometer interconnection is realized by a single 15-pin connector standard "D". A single USB cable between the film densitometer and the computer make possible the connection between the electronic compartment and computer.

The film densitometer is connected to a computer with RTD 4 software-5.2 version, used to obtain the corresponding curve of the investigated films, for different dose distribution determinations. The interface makes possible the collection and drawing of the investigated film dose distributions. The output signal is presented as a relative density or as a dose voltage representing a percentage (usually 0% to 200%). Multidata's Realtime Dosimetry Software provides radiation response correction

(Fig. 1) using table look-up to convert OD measurements to absolute or relative doses.



(a)



(b)

Fig 1. (a), (b) the radiation response curve properties in MULTIDATA densitometer program.

Films used to obtain the experimental results in this paper, have been made in „Prof. Dr. Al. Treistoreanu" Oncologic Institute Bucharest, and the initial interpretation of the radiographies was made by a specialist person in the above mentioned institute.

2.4 Irradiation target determination

ICRU Report 50 and 60, diffines and describes some target and volme helping to the 3D treatment planning and representing the basic elements to obtain some accurate information about the radiation dose to be used in the radiotherapy process. Fig. 2 shows the interest volume described below.

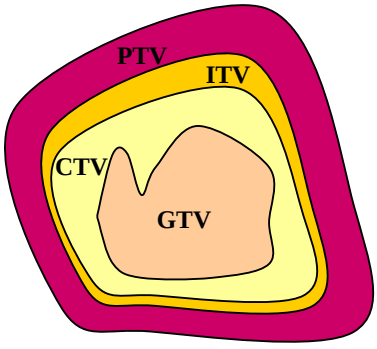


Fig. 2. Graphical representation of the volumes of interest.

The defined volumes in the above publications are: a) GTV - gross tumor volume is the gross palpable or visible/demonstrable extent and location of malignant growth, usually based on information obtained from a combination of imaging modalities (CT-Computed Tomography, Magnetic Resonance Imaging-MRI, ultrasound, etc.), diagnostic modalities (pathology and histological reports, etc.) and clinical examinations; b) CTV-clinical target volume – is the tissue that contains a demonstrable GTV and/or sub - clinical microscopic malignant disease, which has to be eliminated; this volume has to be treated adequately in order to achive the aim of the therapy. The CTV usually includes the area directly surrounding the GTV, which may contain microscopic diseases and other areas considered to be at risk and requiring treatment (CTV = GTV + 1 cm). The CTV is an anatomical-clinical volume and is usually determined by the radiation oncologists, often after other relevant specialists such a pathologists or radiologists have been consulted; c) ITV-internal target volume consists of the CTV plus an internal margin. The internal margin is designed to take into account the variations in size and position of the CTV, in function of the area where it is located; other variations can be envolved due to the organ motion such as lungs breathing and the bladder; d) PTV-planning target volume is a geometrical concept defined to select the appropiate beam arrangements, taking into consideration the net effect of all possible geometrical

variations, in order to ensure that the prescribed dose is actually absorbed in the CTV (PTV = CTV + 1 cm).

2.5 Physical treatment plane elaboration

External radiotherapy using photon beam is usually obtained with more radiation beams with the aim to obtain a uniform dose distribution inside the target volume and the smallest possible dose in the healthy tissue adjacent to the target. Modern radiotherapy with photon beams is realized using a variety of energies and dimensions of the beam field, with respect to one of the two conventions: a constant source to surface distance maintained (SSD) for all the beams or the realization of an isocentered device with a source to axis distance (SAD) constantly maintained. After discovering of the tumor dimension and localization it, is very important to have the physical treatment planning and, after the tumor and near tissue removal, the irradiation made with a minimal risk for the area the tumor was removed off, defined as a target volume for treatment. For example, in mammography, after the tumor removal, the target volume must to be redefined. This redefinition has the aim to determine the effects that can occur after irradiation, like: breast pain, poor cosmesis and cardiac toxicity [3]. Redefinition is starting of the fact that the surgery was not performed in the plane of the breast duct system, creating a potential for having three-dimensional clearance variations following to tumorectomy. Thus the clinicians have concluded empirically that defining a treatment margin of 10-12 mm. That margin will need to be proven by the standard of practice, to avoid the skin irradiation with a big radiation dose and avoid necrosis.

3. Results and discussion

The peak kilovoltage used in mammography should be between 23 and 35 kV, and the used filter width must be between 0.24 and 0.43 mm [4]. Breast tissue thickness means the compressed breast, as measured in the center of the view field and should be between 2 and 8 cm. The glandular fraction means to the composition of the breasts, as partitioned between glandular tissue (the radiation-sensitive component) and the adipose tissue. So called fatty breasts or fibrous breasts would have a value of glandular fraction closer to 0.0, while the dense breasts would have a glandular fraction closer to 1.0. Theoretically the breast tissue is composed of half adipose tissue and half glandular tissue, so the glandular fraction would be equal to 0.5. Skin entrance exposure is the exposure (roentgens) for a particular mammographic technique, as measured free in air above the surface of the breast. The value used depends on the technique and will considerably vary based on the breast thickness. Typical values range is between 0.5 R (thin breasts) and 5.0 R (thick breasts).

3.1 Tumor area location based on mammography

The purpose is that the blackening densities should be capture on mammography, reflecting the cumulative exposure to risk factors [5]. The breast tissue densities are linear, function of age.

Fig. 3 shows the dependence between densities percentage for different age groups. A significant difference of the mean percent density for age group 40-50, is observed.

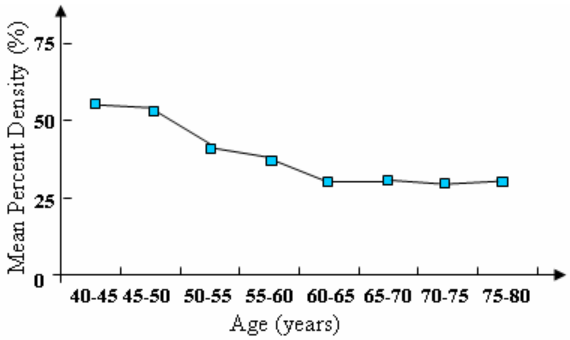
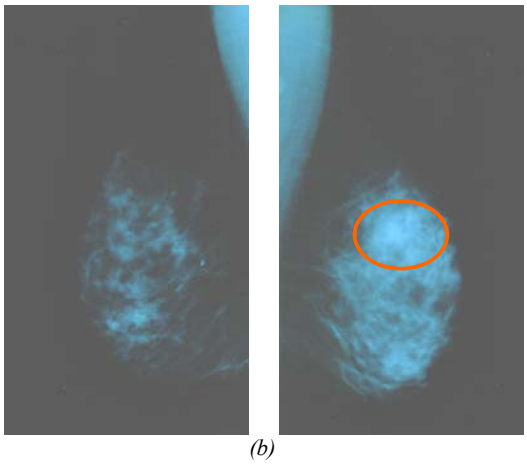


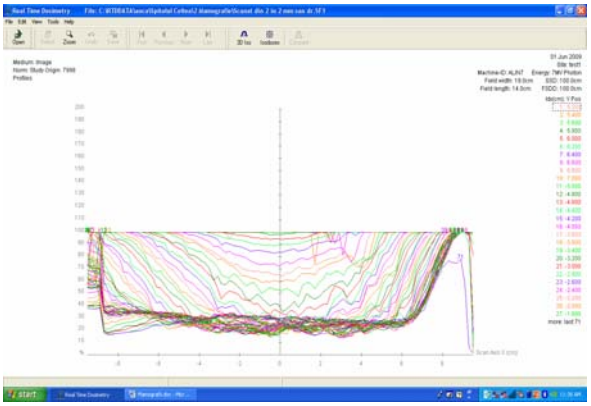
Fig. 3. Mean percent density as a function of age group.



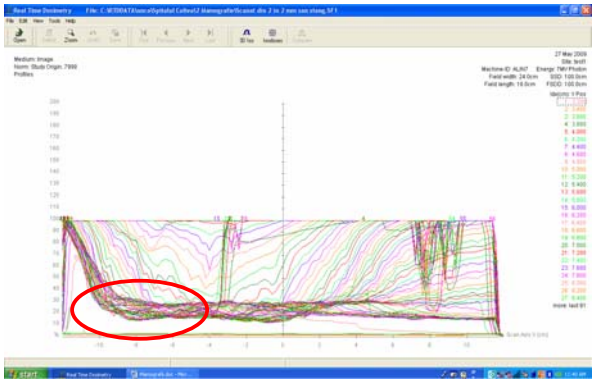
(a) *(b)*

Fig. 4. Mammography representation for the same patient: a) right breast - healthy, b) left breast – having tumoral growth.

Fig. 4 presents the mammography for the right breast (a) and the left breast (b) at the same patient. In the figure it can be seen that the left breast mammography presents an area in which the blackening density is smaller then the rest of the film and than the right breast mammography (excluding the area with low blackening density corresponding to pectoral muscle). In that area the oncologist may see a tumoral growth. Both mammographies are investigated using the film densitometer to evidence the area in which the tumor is located.



(a)

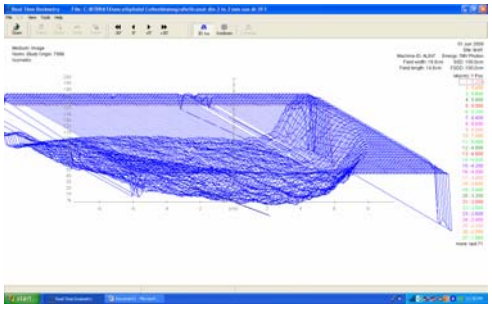


(b)

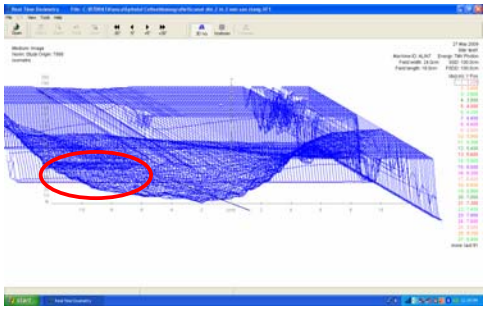
Fig. 5. 2D blackening distributions corresponding to the investigated mammography: (a) the right breast, (b) and the left breast.

Fig. 5 (a) represents the 2D blackening distributions, for the mammography made for the right breast, and in Fig. 5 (b) 2D blackening distributions, for the mammography made for the left breast are represented. Note that in figure 5 b), the area in which the tumor is, presents small blackening percentage, corresponding to the low area in which the radiation dose reached the film, the rest of the radiation being stored in the tumor, which has the mass density bigger than the density of the healthy tissue.

Fig. 6 (a) and (b) present the 3D blackening distributions for both mammographies: (a) right breast and (b) right breast. In the left part of Fig. 6 (b), one can observe the area in which the tumor is located, the blackening density values from that area being smaller, comparative with the blackening density from the same area of the Fig. 6 (a).

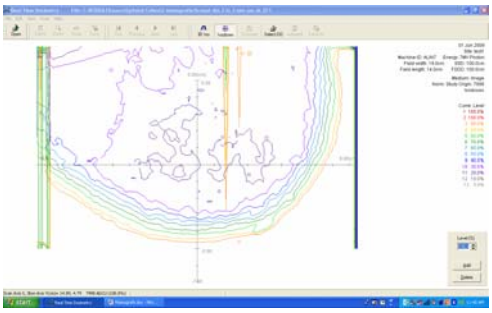


(a)

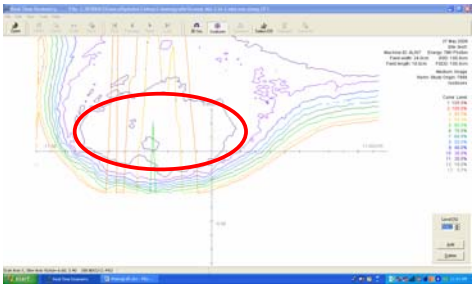


(b)

Fig. 6. 3D blackening distributions corresponding to investigated mammography: (a) the right breast, (b) and the left breast.



(a)



(b)

Fig. 7. Isodose distributions corresponding to investigated mammography: (a) the right breast, (b) and the left breast.

Fig. 7 (a) and (b) presents the isodose distributions corresponding to the blackening isodensities distributions for both mammographies. In the read line ringed area, in the corresponding figures of the left breast, one may see the location of the tumoral growth.

3.2 Lumbar area radiography investigation

Similar to the above mammography, a lumbar area radiography was investigated, enclosing a pelvis tumor, located in the red line ringed area in Fig. 8. Because this tumor has a smaller mass density than the bone and the organs in that area, it appears on the film as a spot having the blackening density bigger.

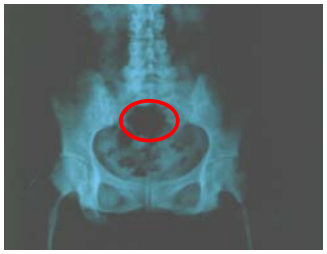
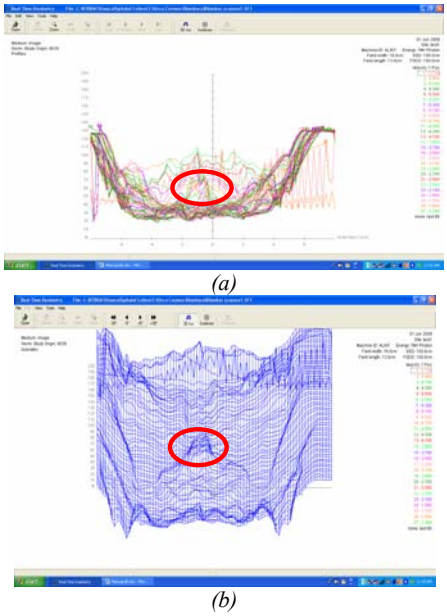


Fig. 8. The lumbar area radiography.

2D blackening distribution representation for the pelvis area radiography is presented in Fig. 9 (a), where the area with blackening density bigger (60 – 80 %) where the pelvis tumor is located may be seen.

In Fig. 9 (b) the 3D blackening distribution for the lumbar area radiography may be seen. In this figure the area in which is located the tumor is clear delimited (i. e. the area in which the blackening percent values are between 60 and 80). The areas with the biggest blackening densities (≈ 130) are corresponding to those film surfaces on which the radiation reached directly, passing no kind of tissue.



(a)

(b)

Fig. 9. (a) 2D blackening distributions for the lumbar area distributions; (b) 3D blackening distributions for the lumbar area distributions.

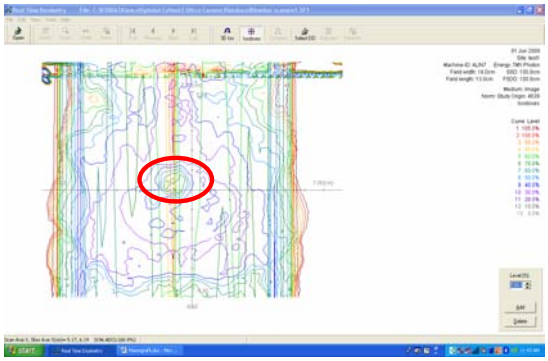


Fig. 10. Isodose distributions corresponding to lumbar area radiography.

Fig. 10 provides the isodose distributions corresponding to blackening distributions from the investigated radiography. One can see that near the contour of the tumoral growth, the presence of the vertebral column bone.

6. Conclusions

The used film densitometer is an accurate dosimetric system, used as a periferal device for measuring the information related to the relative density/dose, obtained on a film exposed to ionizing radiations [6].

This work presents the 2D, 3D blackening distributions and isodose distributions for three clinical radiographies: two mammographies and a lumbar area radiography.

The method presented and used in this work, is a "quantitative" method for finding and localting the tumors. The shortcoming of this method is that employing it one can find the type of the tumoral growth (benign or malign), but necessarily requiring further investigation through other specialized method.

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