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VIEWPOINT

GUIDELINES FOR HIGH QUALITY MAMMOGRAPHY SCREENING

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A b s t r a c t: Mammography is a method of choice for breast screening characterized with great effectiveness in early detection of breast cancer. High quality mammography means the best image quality with minimal breast radiation. The aim of this review is to determine the factors that reduce the MGD (mean glandular dose) in order to achieve minimal breast radiation without compromising the image quality. The implementation of quality standards in mammography screening includes the following activities: technological improvements, optimal calibration of the equipment in mammography centers according to the breast thickness and tissue composition, adequate assessment of the mean glandular dose and elimination of the present causes for poor quality mammograms. These recommendations are dedicated to the medical staff in radiology centers, and to the physicians who have clinical practice with female population undergoing a regular mammography screening. Quality control in standard mammography screening examination can contribute to reducing the morbidity and mortality of breast cancer.

Key words: mammography, radiation dosage, quality control.

1. Background

Mammography is the most reliable method of choice for breast screening. Mammography has to be with high quality, high sensitivity range and high specifity, since it is one of the several screening tools for early detection of breast cancer in addition to clinical and self- breast examination. The sensitivity of mammography depends on the quality of the equipment, competence of the staff, breast thickness and breast tissue composition. During mammography the breast is compressed and in standard protocol two views are taken, cranio-caudal (CC) and mediolateral (ML) oblique views. Mammographic imaging system have to provide high contrast, which is capability of the system to make visible small differences in soft tissue density and good sharpness, as a capability to make visible small details.

1.1. Mammography screening, biophysical aspects-benefits and risks

Mammography is a very effective radiological procedure. The most important benefit of the mammography is the positive predictive value for breast cancer ranges from 20% in women under the age of 50 to 80% in women aged 50 to 69 years. [1] Early detected breast cancer enables successful long- term control of this disease and a good prognosis. On the other hand there is a risk of carcinogenic effect produced by the radiation dose because the breast tissue is radiosensitive. The average glandular dose – AGD (terminology used by the European Commission, 1996), inherent to the tissues which are most sensitive to radiation is the dosimetry quantity generally recommended for radiological risk assessment. Unfortunately there is no minimum dose of radiation that can be defined as absolutely harmless. The carcinogenic risk exists as cumulative one, referring to the absorbed glandular dose. The risk is acceptable, in comparison with the benefits of the mammography screening

Although there has been certain improvement in the number of women who have been included in mammography screening, the results from the research done by Antevska S. [2] showed insufficient effectiveness in the number of early detected cancers, only 1% of detected breast cancers were Ca in situ-noninvasive carcinomas. This is due to many reasons: lack of education of the female population for the benefits of regular mammography screening, lack of encouragement offered by the physicians, financial and health insurance barriers and poor quality mammograms. The latest published results have shown high percents of early detected carcinomas, 25 to 30% of all detected breast cancers with mammography screening [3].

The American Cancer Society and American College of Radiology recommend annual mammography to every woman at the age 40 to 49 and to women over the age of 50. More aggressive screening or biennial high quality, two view mammography is recommended to women who have risk factors for breast cancer, such as: age over 50, family history of premenopausal breast cancer in the first degree relative, familial cancer syndrome, and hormonal factors like early menarche, late menopausa, late parity and nulliparity [4, 5].

2. *Factors that influence on the breast radiation dose*

2.1. *Technological advances*

Today it is very important to assess the factors that affect the breast radiation dose in order to determine the most effective protocol which include optimal radiation dose control without compromising the image quality.

Good image quality can be achieved by using low kilovolt-peak (kVp) settings, but their negative characteristics are high radiation dose to the breast and motion unsharpness of the image. Recently technological advances have led to lower radiation dose in screen film mammography because of employing adequate technology as an independent factor that can provide good image quality. Technological advances are: dual anode x-ray tubes equipped with molybdenum (Mo) and rhodium (Rh), or Mo and tungsten (W) combined with Mo, Rh or Al filters, (Mo/Mo, Mo/Rh, or W/Al). Use of automatic exposure control (AEC) and automatic beam quality selection mode (AOP-automatic optimization of the parameters) provides optimal selection of kVp, mAs,target material and filter according to breast thickness and breast tissue composition [6, 7].

Several scientific reports have demonstrated that Mo/Mo target /filter combination produces the best contrast. According to many authors, the best image quality is provided by using W or Rh anode tube with an Rh filter in thick and dense breasts. Use of proper kVp /anode/filter combination based on breast thickness and breast tissue composition is advised by many authors [8, 9].

Selection of screen – film combination is one of the factors that affect the global radiation dose [10]. Technically standard mammography protocol includes two views. The central beam angle in ML projection varies from 30° to 60°. In a study of Brnic *et al.* [11] where two different angles of MLO were compared (45° and 60°), the use of 60° angle permitted a significantly lower MGD. Oblique mammograms done with 60° angle are recommended for small and pendulous breasts (fibro glandular tissue is projected on a larger film area with less effect of superimposition) although standard use of 45° is common.

In 1994 the Food and Drug Administration in USA recommended mammography quality standards as well as mandatory certification of every mammography center in order to implement high standards and image quality for mammograms [12]. At present European Protocol on dosimetry in mammography and Guidelines for quality assurance in mammography screening are effective in Europe.

Recent investigations about the implementation of the quality standards in mammography screening in R. Macedonia have been done by Gersan V. and presented on the I-st National Conference for Physics in Medicine and Biomedical Engineering [13]. According to these examinations in 16 different mammography centers, the image quality of standard mammograms is bellow the standards recommended by the EU (mostly because of the bad technologic characteristics of the equipment), yet the mean radiation glandular dose is not superior to the maximum allowed doses.

2.2. Breast thickness and breast tissue composition

In general the breast radiation dose is affected by breast tissue composition and thickness of the mammary gland. The AOP mode and the AEC provide automatic selection of the target material, filter type, kVp, and mAs. Selecting the semiautomatic beam quality, the tube voltage (kVp) and anode/filter combination are set by the technician according to the tissue density and thickness of the compressed breasts. Sometimes the variable kVp protocol is suggested since the optimal energy necessary for breasts of different thickness and composition is different [14]. In this context it is suggested that variable kVp technique has significant effect both on the image quality and the dose. The ultimate aim is to achieve the best image quality at the lowest possible dose. The appropriate doses obtained in thicker and denser breasts are being significantly higher than in fatty breasts. Fatty breasts are more often thicker, but they need less exposure than dense breasts because lower penetration is needed for adipose tissue and a higher for the glandular one. Thus the selection of exposure factors, screen-film combination, radiation output of the x-ray tube has to be based not only on breast thickness but on breast tissue composition as well.

Breast tissue density of each patient can be determined from previous mammograms. If previous mammograms are not available breast tissue density is hard to be predicted. Known factors that influence breast tissue density include: woman's age, her hormonal status and body mass index-(BMI) [15]. The age and the BMI are inversely related with the breast tissue density. After cessation of the ovarian function (menopause), natural or artificial (hysterectomy with bilateral oophorectomy), breast density as a measure of stromal and epithelial breast tissues decreases whereas an increase of adipose tissue appears. Fig. 1 . Women known to have lower breast density are postmenopausal, age ≥ 50, with higher BMIs.

It has been found that the compressed breast thickness tend to increase up to the age of 60. The trend for breast glandularity is to decrease with increasing compressed breast thickness, (absolute difference in breast glandularity of 80% between breasts of 30 and 90 mm compressed thickness) [16]. Increased breast density is a common finding in women under the age of 50 (premenopausal and perimenopausal) and in lean women with lower BMIs. Ethnic diversity influences on breast tissue composition in female population. For example, the breast tissue density is significantly higher in Italian women than in UK women for the same size of breasts [17]. There are also differences in mammary gland densities between Asian-Americans, African-Americans and Whites [18].

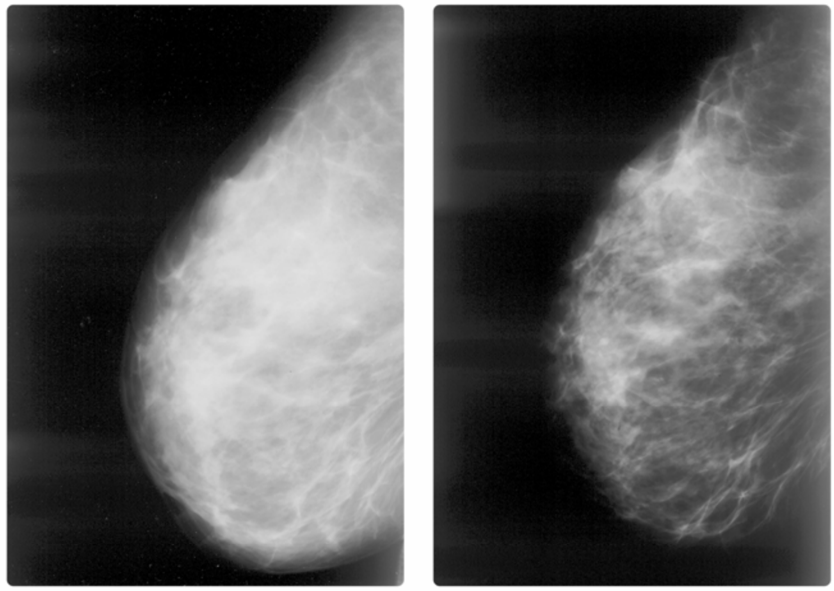

Figure 1 – (A), (B) Medio-lateral (oblique) mammograms of an individual female, in which the image of breast density vary in the 3 years postmenopausal period of time. The changes represent reduction of breast density (from A→B) or the trend in the postmenopausal period is generally towards a less dense (higher percentage of fat) breast tissue

Слика 1 – Медио-латерални мамографии на женска индивидуа во постменопауза направени во 3-годишен временски интервал, на кои постои разлика во густината (дензитетот) на жлезденото ткиво. Снимките презентираат редукција на густината на жлезденото ткиво (од A→B) или трендот во постменопауза е кон намалување на густината на жлезденото ткиво и зголемување на процентот на масно ткиво

In fact, most of the factors associated with the variability of the breast tissue density still remain unexplained. The presence of dense breast tissue is an independent risk factor for development of breast carcinoma.

The estimation of mammary gland density can be done by using different methods. The methods of Wolfe [19] and a modification of this method proposed by Tabar [20] are qualitative and based on perceptual judgement of the diagnosticians of the breast morphology on Rx mammogram. There are differences in their assignement of a region of parenchymal tissue to one of Wolfe's four classes.These methods are characterized with great heterogenity in breast cancer risk estimations. The method established by the American College of Radiologists-BIRADS (Breast Imaging and Reported Data System) used in clinical radiology practice in USA is standardized reporting of visual assessment of mammographic findings. Also a classification described by Boyd *et al.* (SCC) who developed a computer assisted technique of measuring percentage mammographic densities is a method of quantitative assessment of percentage breast density. [21, 22] table 1. Highnam and al. developed Standard Mammogram Form as a quantitative measure of non-fat tissue at each location on digitized mammogram image.This method effectively removes tube voltage and exposure time which affect the appearance of the mammogram. [23]

Table 1 – Табела 1

Classifications of mammographic density

Класификации на мамографската густина

	Wolfe	BI-RADS
Description	Visual classification based on the extent and distribution of the parenchyma and fat	Standardized reporting of visual assessment of mammographic findings by the American College of Radiology-BI-RADS
Categorization	N1– completely fatty breasts P1 – mainly fatty breasts with prominent ducts, up to 25% density P2 – prominent ducts, more than 25% density DY – no visible ducts, diffuse and extensive nodular density	Category 1 – almost entirely fatty (< 25% dense) Category 2 – scattered fibroglandular densities (25–50% dense) Category 3 – heterogeneosly dense (51–75 % dense) Category 4 – extremely dense (> 75 % dense)

BI-RADS, Breast Imaging Reporting and Data System

3. Assessment of the average glandular dose

The average glandular dose (AGD) or mean glandular dose (MGD) cannot be measured directly. It is estimated through the relationship- $D = K_{45} \times g_{53} \times c_{53} \times s$. K_{45} is the entrance surface air kerma (in the absense of scatter) for 4.5 cm thickness of Perspex (PMMA), while g is a conversion factor which converts incident surface air kerma to glandular tissue dose, so g_{53} converts the incident air kerma for 53 mm thick breasts. Factor c-corrects for any difference in breast composition from 50% glandularity, or c_{53} is a conversion factor which allows for the breast glandularity of the 53 mm thick standard breasts and factor s-spectral correction factor, corrects for any difference due to the use of different x-ray spectrum. Measurements of the AGD can be obtained by the phantom method and the patient method. The phantom method is based on the measurement of reference breast phantom – 45 mm thick polymethyl-methacrylate (PMMA) phantom which represents a standard breast 50 mm thick. The female breast has semicircular cross section, 0.5 cm outer layer composed of adipose tissue and central area as an equal amount of glandular and adipose tissue. However, the reference breast phantom was treated as a reasonable representation of an average female breast, but in clinical experience the proportion between these tissue parameters is variable. Air kerma is radiation quantity that is used to express the radiation concentration delivered to a point, like the entrance surface of the patient's body. The quantity, kerma, originate from the acronym KERMA (kinetic energy released per unit mass-of air).

The entrance surface air kerma (ESAK) or the entrance surface dose is measured free in air (without backscatter) at a point corresponding to the entrance surface of the phantom. For the ESAK measurements a mammogrphic ion chamber or thermoluminescence dosimeters can be used. MGD is calculated using the conversion factors derived from the Monte Carlo calculations. The conversion factor g is dependent on HVL (Half Value Layer) of the spectra estimated from the results of Monte Carlo simulation procedure as a computer simulation of a model breast phantom. [24] The conversion factors were evaluated for the breast thickness ranging between 2–8 cm. For instance, it is considered that 4–6 cm of breast thickness corresponds to equal proportion of glandular and adipose tissue. [25]

The patient method is more reliable because there are physiological variables in breast tissue composition which have significant effects upon dosimetry evaluation. In the patient method doses in real patients are estimated for each breast by using the post-exposure mAs, tube voltage, and x-ray beam quality specific tube output factor (mGy/mAs). A conversion between incident air kerma and MGD is made on the basis of the conversion factors. A survey of actual patient doses is needed to assess the characteristics of the population of patients and the risk of radiation induced cancer. For this purpose previously obtained data from a representative selection of patients can be used. The AGD is higher in more dense breasts since they require more exposure to achieve good radiologic image quality.

The use of the phantom method for the calculation of AGD results in 13% overestimation of dose values.The use of conversion factors related to glandularity and compressed breast thickness reduce the error range to 1%. As a result of aging and the decrease of the glandular breast tissue it would be necessary to reduce the AGD at each screening survey, thus decreasing the radiation risk.

The spectrum of glandular and adipose tissue breast composition data for women of different age helps to prepare tables with conversion factors in order to determine the optional AGD (average glandular dose). According to these parameters over and underestimates of the AGD can be avoided.

4. Conclusions

The aim of this presented review is to highlight the importance of performing high quality mammograms using the lowest possible dose. The implementation of quality standards in mammography screening is essential to prevent causes for poor quality mammograms and to reduce morbidity and mortality from breast cancer. It is necessary that all mammography centers should be certified and controlled in order to follow the established guidelines while performing mammography screening.

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Резиме

ВОДЕЧКИ ПАРАМЕТРИ ЗА ВИСОКОКВАЛИТЕТЕН МАМОГРАФСКИ СКРИНИНГ

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Мамографијата е метод на избор за редовен контролен скрининг на дојките, бидејќи се карактеризира со голема ефективност во раното откривање на карциномот на дојките. Висококвалитетна мамографија значи дека е постигнат најдобар квалитет на снимките со минимално зрачење на ткивото на дојката. Целта на овој ревијален труд е да ги детерминира факторите кои ја редуцираат МГД (средната гландуларна доза) со цел да се постигне минимално зрачење без да се компромитира квалитетот на мамографските снимки. За имплементација на стандарди на квалитет во мамографскиот скрининг се препорачуваат следниве активности: технолошко подобрување на опремата во мамографските центри, оптимално калибрирање на истата во однос на дебелината на дојките, како и во однос на составот на ткивото на дојките (соодносот меѓу масното и жлезденото ткиво), адекватна процена на средната жлездена доза, како и отстранување на причините за неквалитетните мамографски снимки. Овие препораки се наменети за медицинскиот персонал во радиолошките и мамографските центри, како и за лекарите кои во клиничката пракса работат со популација на жени кои подлежат на редовни контролни мамографски прегледи. Контролата на квалитетот при стандардните мамографски прегледи може значајно да го редуцира морбидитетот и морталитетот од карцином на дојките.

Клучни зборови: мамографија, доза на радијација, контрола на квалитетот.

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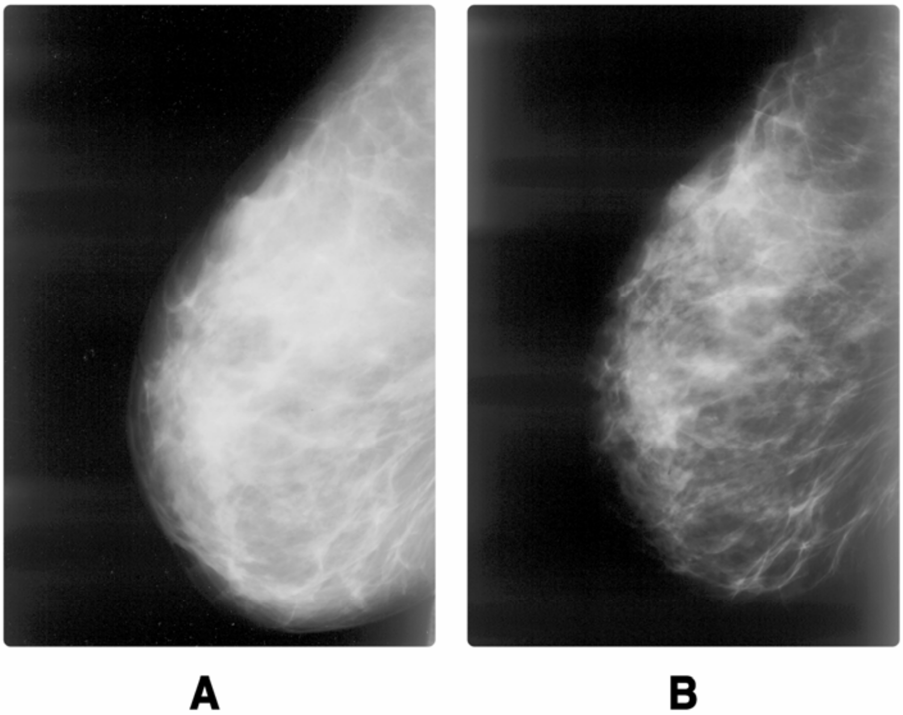
BI-RADS, Breast Imaging Reporting and Data System

Fig.1 (A), (B)
Medio-lateral (oblique) mammograms of an individual female, in which the image of breast density vary in the 3 years postmenopausal period of time . The changes represent reduction of breast density(from A→B) or the trend in the postmenopausal period is generally towards a less dense (higher percentage of fat) breast tissue,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