OPTIMIZATION OF MAMMOGRAPHIC IMAGES*

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Abstract **OBJECTIVE: The aim of this study is the optimization of mammographic images with a considerable radiation dose reduction. MATERIALS AND METHODS: In the present study the X-ray beam was calibrated for each tension (kVp), aiming at determining the best combination between kVp and mAs, resulting in optical densities of about 1.0 above the base-plus-fog density. RESULTS: This study will bring into question the methods for X-ray beam calibration, the choice of the best image by means of visual grading analysis, comparisons between doses and tube load (kVp × mAs) delivered by the techniques described in this study and by those adopted in the clinical routine at Service of Diagnostic Imaging of Faculdade de Medicina de Botucatu Clinics Hospital, Botucatu, SP, Brazil. Excellent breast radiographic images have been obtained with doses and tube loads reduction of respectively 36.8% and 46.2% in comparison to those employed in our institutions' clinical routine. CONCLUSION: This study is a contribution to the optimization of the risk-benefit ratio for patients and cost-benefit ratio for the institution.**
Keywords: Mammography; Homogeneous phantom; Quality control; Dose reduction.

Resumo *Otimização de imagens mamográficas.*
OBJETIVO: Este trabalho tem como objetivo a otimização de imagens mamográficas, com consideráveis reduções de doses. MATERIAIS E MÉTODOS: Neste estudo o feixe de raios-X foi calibrado para cada tensão (kVp), de modo a determinar a melhor combinação de kVp e mAs que irá proporcionar uma densidade ótica (DO) em torno de 1.0 acima da base mais véu do filme utilizado. RESULTADOS: Serão discutidas questões sobre os métodos empregados para a seleção de parâmetros de exposição do feixe de raios-X, seleção da melhor imagem utilizando o método de avaliação gradativa visual, comparações entre as doses e carga do tubo (kVp × mAs) proporcionadas pelas técnicas determinadas neste estudo e pelas utilizadas na rotina clínica do Serviço de Diagnóstico por Imagem do Hospital das Clínicas da Faculdade de Medicina de Botucatu. Neste estudo foram obtidas imagens radiográficas de mama de excelente qualidade, com redução de dose e carga de tubo, respectivamente, de 36,8% e 46,2%, quando comparadas com a técnica utilizada pela rotina clínica da instituição. CONCLUSÃO: Esta pesquisa vem contribuir com a otimização da relação risco-benefício para o paciente e custo-benefício para a instituição.
Unitermos: Mamografia; Fantoma homogêneo; Controle de qualidade; Redução de dose.

INTRODUCTION

In Brazil, deaths caused by breast cancer represent 16% of the mortality related to malignant neoplasms among women(1). The early detection or screening is the process aimed at detecting a determined type of cancer in its early phase, before the appearance of any symptom(2). In this case, the mammography is the method of choice, since it may detect up to 90% of breast cancers. However, neoplasm detection by means of a mammogram depends on factors associated with parameters like screen-film system, radiographic techniques, an adequate angulation of the X-ray tube, correct positioning of the patient, satisfactory compression and exposure of the breast(2–3).

Presently, in Brazil, there are more than 2,700 mammographs, corresponding to an average of one for each 32 thousand inhabitants(4). An alarming data is that more than 60% of these mammographs are not submitted to a quality control process(4). Typically, mammographic images acquired in services of diagnostic imaging present a very low quality level, likely to generate a significant rate of false-negative or false-positive results in the clinical routine(4). It is important to mention that the image quality depends on optical densities (OD) satisfactory to the physiological response of the human eye, besides a good visualization of tissues relevant for a safe medical diagnosis. The breast tissue presents similar density and effective atomic number, so the contrast produced by interaction between radiation and this tissue is low(5). Therefore, the mammographic examination requires the highest technical standard because of the breast tissue structure itself and the very particular geometry of breast radiography(5–7).

In the present study, we propose a procedure for selection of exposure parameters appropriate for any screen-film system, aiming at achieving radiographic techniques which are able to deliver images of a typical 3 cm thickness compressed breast, with higher acceptance rates in tests of gradual visual evaluation(8.9), and presenting reasonable dose reductions.

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MATERIALS AND METHODS

In the present study, we have utilized a phantom approved by Colégio Brasileiro de Radiologia (Brazilian College of Radiology) for accreditation in mammography. The homogeneous portion of this phantom and the portion including analytical details were utilized in a way to simulate a 3 cm-thickness compressed breast with an average composition (50% glandular tissue and 50% fat tissue).

The homogeneous portion of this phantom was utilized for selection of X-ray beam exposure parameters[10,11], in a way to obtain radiographic techniques responsible for the yielding of an OD satisfactory to the human eye. The optical densities originated from sensitometric curves produced by the time scale sensitometric method[10–12]. This is a very efficient method for experiments in radiodiagnosis[10–13]. Figure 1 presents an experimental arrangement utilizing the sensitometric method adopted in this study where a phantom can be observed (a) positioned on a shield system; (b) mounted on the screen-film bucky tray (c). In this procedure, a manual exposure control was adopted in a way to expose, on the screen-film system, only previously established regions, varying the exposure time and maintaining a constant kVp. The result of this procedure is presented on Figure 2 showing different ranges of optical density on the film as a result of the variation of the exposure time.

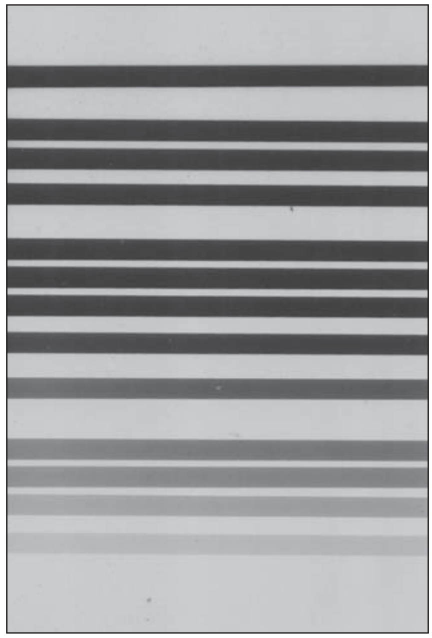

Figure 2. Optical density ranges obtained through the time scale sensitometric method.

The relation between the logarithm of relative exposure (LRE) and the DO yields a response curve or sensitometric curve of the screen-film system for a determined kVp[(10–13)], as per Figure 3. The best OD yielded from the linear region of sensitometric curve. In this procedure, the mAs corresponding to the OD of the linear region of the curve were combined with the selected kVp , generating a set of seven radiographic techniques. These techniques were utilized for obtaining images from the phantom with analytical details, leading to the production of images with different ODs, but with a same radiographic contrast because of the constant kVp. Such images were subjectively analyzed by 11 specialists in Radiology, utilizing the method of gradual visual evaluation[8,9]. These professionals identified the more appropriate gray tone for breast images production. This procedure was performed for a kVP range between 23 and 31, 1 kVP step, so for each kVP value we have an image selected with the best gray tone (OD) for the physiological response of the human eye. These radiographic techniques are shown in Table 1.

It is important to note that all the images produced according the techniques included in Table 1 present a same gray tone, however, one differs from each other in terms of radiographic contrast, since the images are produced with different kVp. Once again, the method of gradual visual evaluation was utilized to identify the image providing the best visualization of the phantom structures, i.e., the best radiographic contrast for a typical 3 cm-thickness compressed breast.

The radiographic technique illustrated in Table 1, capable of providing the best visualization of the phantom structures (28 kVp and 25 mAs), should be associated with the automatic exposure control in order to achieve a same exposure rate (constant kVp) in the screen-film system. This procedure is compatible with the necessity of an automatic exposure control in mammographic examinations[7,14].

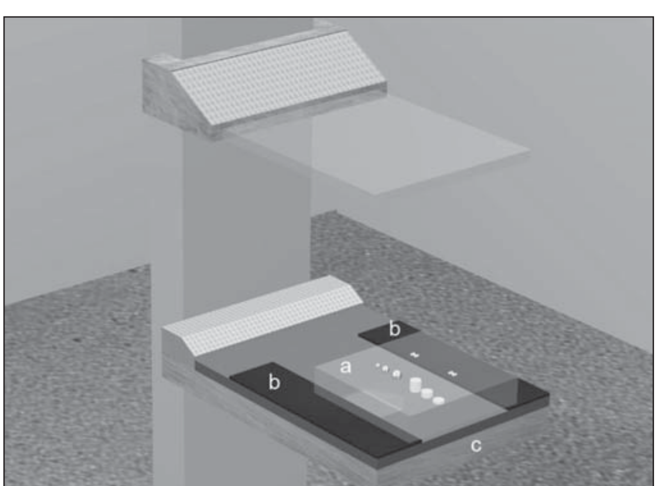

Figure 1. Experimental arrangement of the time scale sensitometric method.

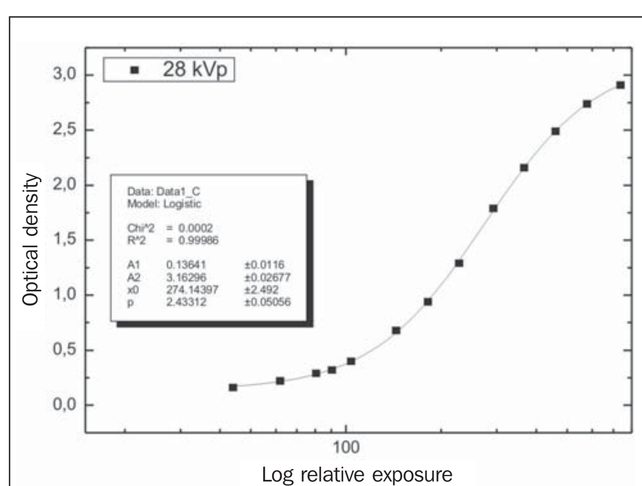

Figure 3. Typical curve obtained through the time scale sensitometric method utilizing a 3 cm homogeneous acrylic phantom with 28 kVp.

The best image obtained in the present study was compared, by means of gradual visual evaluation, with those images produced in the clinical routine of Faculdade de Medicina de Botucatu – Universidade Estadual Paulista (HCFMB-Unesp) Clinics Hospital. The clinical routine image was determined by a technician in Radiology duly instructed to consider the phantom as a typical 3 cm-thickness compressed breast. Thus, the technician selected three kVp and utilized the mammograph´s automatic exposure control in a way to produce three images of the analytical phantom. One image was selected by means of gradual visual evaluation, as the best in a set of images produced with the clinical routine techniques.

Finally, with the aid of lithium fluoride (LIF) termoluminescent dosemeters[15], radiation doses were monitored on the phantom entrance surface, utilizing the optimized radiographic techniques found in the present study and those utilized in the HCFMB-Unesp service routine.

In the present research, we have utilized a General Electric Senographe 600T – Senix H.F mammograph, with Mo/Mo target/filter combination, IBF-Medix (18 × 24) cm film in combination with a Kodak Min-R intensifying screen, a standalone Momoray Detail HT-300 (Agfa) automatic processor, MRA densitometer and sensitometer. The possible processor variations were evaluated with a Victoreen 21-step dual color model 07-417 and a MRA digital densitometer. It is important to note that the clinical imaging diagnostic routine utilizes the above mentioned screen-film system.

RESULTS

The Table 1 presents the kVp evaluated in the present study with the respective mAs which produced ODs satisfactory to the human eye, obtained with the homogeneous phantom utilizing the time scale sensitometric method. It is important to note that the base-plus-fog-density value utilized is 0.20.

According to data shown Table 1, the OD that is most satisfactory to the human eye for visualizing the breast structures is around 1.27. The kVp/mAs combination (in bold types) that has provided the best visualization of the analytical phantom structures corresponds to 28 kVp/ 25 mAs.

The image that corresponds to the radiographic technique found in this study is presented in Figure 4A. The Figure 4B presents the best image produced by the radiographic technique utilized by the clinical routine, simulating a typical 3 cm-thickness compressed breast. The image produced by the clinical routine (Figure 4B) presents a decrease in radiographic contrast with a gray tone around 1.5, difficulting the visualization of structures relevant for a safe medical diagnosis.

Table 1 kVp and mAs combinations utilized for obtaining optical densities more satisfactory to the human eye physiological response, according specialists in Radiology of HCFMB-Unesp, utilizing a homogeneous breast phantom.

kVp ± 0.01	mAs ± 0.01	OD ± 0.01
23.00	80.00	1.26
24.00	63.00	1.27
25.00	50.00	1.26
26.00	40.00	1.26
27.00	32.00	1.27
28.00	**25.00**	**1.27**
29.00	20.00	1.24
30.00	16.00	1.28
31.00	16.00	1.27

The Table 2 includes the radiographic technique determined by this research as well as those utilized in the service routine with their respective doses (in mGy) and tube loads, simulating the exposure of a typical 3 cm-thickness compressed breast.

DISCUSSION

The time scale sensitometry method adopted in the present research allows evaluating the exposures of the sensitometric curve linear region for a given kVp. Therefore it is possible to define the best gray tone for a radiographic image associating it (through exposure evaluation) with

Table 2 Comparison between doses and tube load (kVp x mAs) produced by radiographic techniques obtained in this study and by HCFMB-Unesp clinical routine.

Radiographic technique	This study	Clinical routine HCFMB-Unesp
kVp ± 0.01	28.00	26.00
mAs ± 0.01	25.00	40.00
D (mGy) ± 0.001	2.133	3.688
CT (J) ± 0.1	560.0	1,040.0

D(mGy), dose (in milligray) obtained on the phantom entrance surface; CT(J), tube load (kVp × mAs) with units in joules.

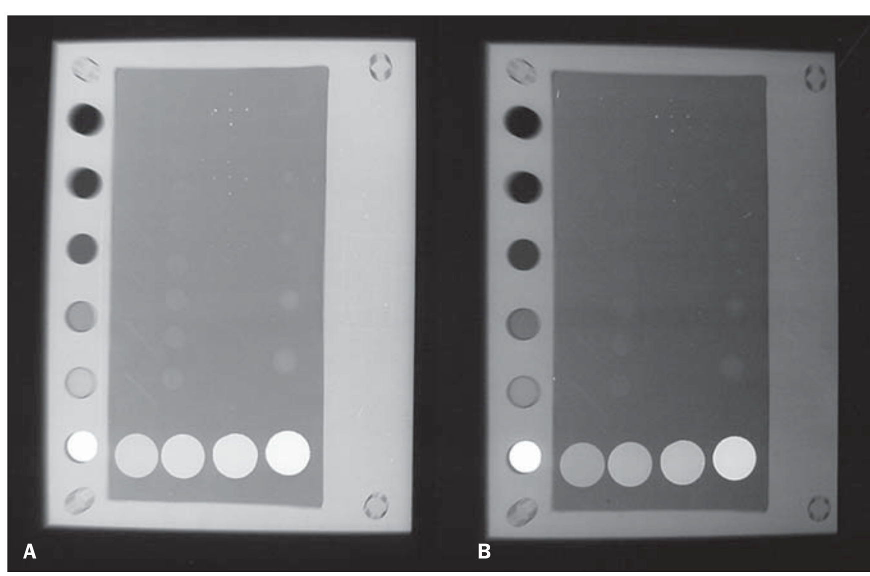

Figure 4. Images from an analytical phantom simulating a typical 3 cm-thickness compressed breast. **A:** Image produced with the radiographic technique obtained in the present study; **B:** Image produced with the radiographic technique utilized in the HCFMB-Unesp clinical routine.

the automatic exposure control for daily procedures. This method may be employed every time any sensitometric factor (screen-film system and automatic processor) presents considerable variations in order to change the image quality. Also, with this method, the best radiographic contrast of the simulated breast can be determined. This procedure must be based on evaluations of kVp that should be combined with mAs, yielding a gray tone adequate to the human eye physiological response.

The kVp and OD values reported in the present study are in compliance with those suggested by American College of Radiology[9], i.e., 28 kVp and an OD above the base-plus-fog density of the film utilized. It is important to note that the observers involved in the evaluation of the mammographic images, were not familiar with the radiographic techniques utilized for the images acquisition.

Another important detail to be taken into consideration is that the automatic exposure control utilized by the sector of diagnostic imaging where this research was developed, was duly calibrated for a more sensitive screen-film system. This explains the gray tone (1.50) in the image produced by the clinical routine (Figure 4B) when compared with those obtained by the present study (Figure 4A). Additionally, the Figure 4B, presents considerable decrease in radiographic contrast as a result of an inadequate kVp value when compared with the image presented in Figure 4A.

Besides the optimization of the image quality, the present study also provides a dose reduction and tube load of respectively 36.8% and 46.2%, when compared with the technique utilized by the HCFMB-Unesp clinical routine, simulating an exposure of a typical 3 cm-thickness compressed breast.

The results of the present study drew the attention of the HCFMB-Unesp clinical staff and immediately the necessary steps were taken to improve the quality of mammographic images in that service. All the screen-film systems were replaced, and the most appropriate processing chemicals for the new screen film system started to be utilized. Also, it is important to note that, currently, the mammography processor undergoes daily quality control tests, a process that contributes to assure the quality of mammograms (about 460 per month) performed in HCFMB-Unesp. Finally, as a result of this research, the institution was granted the seal of quality in mammography by Colégio Brasileiro de Radiologia (Brazilian College of Radiology).

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