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ORIGINAL ARTICLE

Clinical evaluation of breast dose and the factors affecting breast dose in screen-film mammography

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PURPOSE
To investigate the factors affecting the mammographic breast dose.

MATERIALS AND METHODS
The assessment was done on 622 qualified mammograms obtained with use of "variable kV" technique, i. e., semiautomatic mode, in screen-film mammography. Actual breast doses were calculated and analyzed to determine the roles of two screens and three films, two anode/filter selections (Mo/Mo and Mo/Rh), three imaging projections (craniocaudal, 45° and 60° mediolateral oblique [MLO]), breast thickness, and breast composition.

RESULTS
Min R 2190 screen provided about half dose of Min R screen. All films used with the faster screen resulted in similar doses in <50 mm thicknesses (mean, 0.9–1.1 mGy) ($P > 0.05$). The doses were significantly greater in thicker (≥50 mm) breasts, in dense breasts, and in 45° MLO view, compared to the <50 mm breasts, fatty breasts and in 60° view ($P < 0.05$).

CONCLUSION
The affecting factors of dose are many, and their complex interrelations are difficult to control in clinical settings. Well tailoring of kVp/anode/filter combination, selection of faster screens and well matched films are mandatory, while 60° instead of 45° in oblique projection can help reducing the dose. However, tailoring of kVp/anode/filter, which should be based on both breast thickness and composition, is difficult to achieve accurately at all times. Therefore, automatic beam quality control should replace the semiautomatic mode in screen-film mammography practice in order to provide easier and more effective control on breast dose and image quality.

Key words: • *mammography* • *radiation dose* • *measurement*

High-quality mammography is fundamental to maximizing cancer detection. In screen-film mammography, high contrast, which is required to visualize and discriminate tissues with minimal density differences, can be achieved by using low kilovolt-peak (kVp) settings, in addition to grids and high contrast films. The cost of low kVp, however, is high radiation dose to the breast and motion unsharpness in the image. Therefore, image quality and breast radiation dose should balance one another.

Radiation dose in screen-film mammography has been reduced in recent years due to the continuous improvement of X-ray equipment, and the introduction of faster systems and processing technology. Some of the technological improvements are the introduction of dual anode X-ray tubes equipped with molybdenum (Mo) and rhodium (Rh), or Mo and tungsten (W) combined Mo or Rh filters, automatic exposure control (AEC), and the automatic beam quality selection mode (AOP, automatic optimization of the parameters) (1). Numerous studies showed that use of a W or Rh anode tube with an Rh filter in thick or dense breasts provides higher image quality, while resulting in significantly lower dose than a Mo anode tube used with a Mo filter (1–5). The AOP, together with AEC, provide automatic selection of kVp, milliampere-seconds (mAs), target material, and filter, according to breast thickness and composition, as well as pre-adjustment of the settings for the lowest possible dose or highest possible image contrast, according to the preferences of the users (5, 6). Furthermore, new screen-film combinations are very high in contrast. In fact, these products perform better at a lower radiation doses if relatively higher kVp values (27 to 28) are used (7). Despite these technical improvements, the risk of cancer induction resulting from mammography has not been eliminated because there is no minimum dose of radiation known to be absolutely harmless. Benefits from mammographic screening are known to considerably outweigh the hypothetical risk of radiation only when the radiation dose is well controlled, which is particularly important in the 40–49-year-old age group (8, 9).

The main purpose of this study was to assess the factors affecting radiation dose and its interrelationship with the variable kVp protocol used at our institution in order to determine the most effective measures needed for optimal dose control without compromising image quality in screen-film mammography.

Materials and methods

The study included 622 mammograms obtained in 145 patients who were referred to our clinic for screening or diagnostic purposes during 2 consecutive weeks. Each breast was examined with 45° mediolateral (MLO) and craniocaudal (CC) views (n = 580). Additionally, 42 breasts were examined with a 60° MLO view for diagnosis. Breasts that had un-

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dergone conservative surgery and radiotherapy, and recent breast biopsy, or were the source of pain for any reason were excluded because of intolerance to optimum compression. Other than these, no selection criteria were applied.

All mammograms were obtained by 1 of 4 dedicated technicians on the same mammography machine, a GE DMR (General Electric Medical Systems, Milwaukee, WI, USA) with dual anode (Mo and Rh) and dual filter (0.03 mm, Mo and Rh) combinations. This system contains both automatic and semiautomatic beam quality selection modes. The AOP mode, together with AEC, provides automatic selection of target material, filter, kVp, and mAs. In the semiautomatic beam quality selection mode, the tube voltage (kVp) and anode/filter combination are set by the technician according to the thickness of the compressed breast and breast density, while the appropriate mAs is delivered automatically by AEC (Table 1). The current study was performed using the semiautomatic mode only. Depending on breast size, the AEC detector was set to 1 of 3 positions; comparative 45° MLO and 60° MLO films were always taken at the same detector position, and the compression force was applied with a self-limiting mechanism to prevent over compression.

The breast thickness was measured automatically by the machine itself, and read from its control unit. Breast density was determined from previous mammograms. When no previous mammograms were available, breast density was predicted from the patient's age, hormonal status, and body type. Breast density was graded as 1 of 4 types as defined by the American College of Radiology (ACR): entirely fatty (type 1), with scattered fibroglandular tissues (type 2), heterogeneously dense (type 3), and diffusely dense (type 4).

When compressed breast thickness was <50 mm, the Mo/Mo anode-filter combination was used along with 25–27 kVp for type 1 and 2 breasts, and 26–28 kVp for type 3 and 4 breasts. When compressed breast thickness was ≥50 mm, the Mo/Rh anode-filter combination was used along with 27–29 kVp for type 1 and 2 breasts, and 28–30 kVp for type 3 and 4 breasts (Table 1).

At the time of the study, we were using the Kodak Min R screen with Kodak Min R 2000 film, and were considering a replacement of this screen with the faster Kodak Min R 2190 screen. We matched 3 different films with these 2 screens to compare their effects on breast dose. A summary of the 5 evaluated combinations formed with these screens and films is as follows:

1. Agfa Mamoray HDR film/Kodak MinR screen (48 patients),
2. Kodak Min R-S film/Min R 2190 screen (12 patients),
3. Kodak Min R 2000 film/Min R 2190 screen (27 patients),
4. Kodak Min R 2000 film/Min R screen (26 patients),
5. Agfa Mamoray HDR film/Kodak Min R 2190 screen (32 patients).

Within the study period, only the large size (24 × 30 cm) of Kodak Min R 2000 film and only the standard size (18 × 24 cm) of Kodak Min R-S and Agfa Mamoray HDR films were available. Other than the film size, which was selected according to breast size, all film-screen combinations were randomized during the study.

After each exposure, the film-screen combination, breast density, imaging projection (CC, 45° MLO, and 60° MLO), digital readout of thickness (in mm), selected kVp and anode/filter, and post-exposure mAs were recorded by the technician.

All films were developed immediately after exposure in the same dedicated automatic processor, a Kodak Miniloader 2000 P, under constant temperature (33.8°C) and chemical conditions (Kodak RP X-OMAT), with a processing time of 155 s (dry-to-dry time) (Eastman Kodak Company, Rochester, NY, USA) (Agfa-Gevaert N.V., Belgium).

Quality control

Before starting the study, a complete acceptance test of the mammography system was carried out, which included measurements of tube output and exposure reproducibility, kVp accuracy, half value layer (HVL), and performance of AEC. The tube output was measured with a mammographic ion chamber (Radcal Model 9010, 6M) to test the quality of each beam. Kilovoltage accuracy was checked with a noninvasive kVp-meter (Radcal 4082). HVL was determined beneath the compression paddle for all anode-filter-kVp combinations by using aluminum foil with a purity of 99.9% (Standard Imaging). X-ray exposure performance was stable within 4% of the initial value. The mean optical density was measured in breast shaped Plexiglas slices corresponding to 2.3-, 4.9-, and 6.5-cm standard breast composed of 50% glandular and 50% adipose tissue equivalents. All test results were within normal limits suggested by Institute of Physical Sciences in Medicine (IPSM) (10). For retrospective calculation of breast doses, tube outputs, in terms of mGy/mAs, were measured for each kVp and anode/filter combination. In addition, screen-film contact was checked for all screens and processing conditions were checked using sensitometric techniques.

Image quality was the primary prerequisite for the study and was assessed both objectively by phantom studies and subjectively by the observer. For

Table 1. Semi-automatic mode used in the study. Anode/filter combinations and tube kVp manually selected according to the compressed breast thickness and breast composition (BI-RADS types 1 and 2 vs. types 3 and 4).

		kVp		
Thickness (mm)	A/F	Type 1 and 2	Type 3 and 4	n
<30	Mo/Mo	25	26	29
30-39		26	27	74
40-49	Mo/Rh	27	28	162
50-59		27	28	171
60-69		28	29	104
70-75		28	29	35
>75		29	30	5

A/F: anode/filter

the objective assessment, 2 mammographic test objects (CIRS 11A and GE, MTM 100) were used by exposing them at 27 kVp using the AEC. Scoring advantage of GE MTM 100 phantom (General Electric Medical Systems, Milwaukee, WI, USA) was used to compare the image quality of different film-screen combinations on a semi-quantitative base. Scores were assigned for each representative image using the visibility test of different simulation elements, including specks (for microcalcifications), nodules (for masses), and lines (for fibers), in addition to the measurements of contrast (c) and reference optic density (z) values. Measurements of spatial resolution were performed in each film-screen combination using the CIRS 11A phantom (CIRS, Norfolk, VA, USA), which yielded 16–17 lp/mm resolution parallel and perpendicular to the cathode-anode axis of the tube. Thus, all screen-film combinations were objectively qualified for all quality measures before the start of the study.

During the study, phantom tests (GE, MTM 100) and sensitometric tests were performed daily to check the system's consistency. Average measurements were 70 for the total phantom score, 0.53 for the contrast score, and 1.43 for the reference optic density score; all were within recommended limits.

Subjective image quality evaluation was performed along with evaluations of positioning and compression by the same experienced breast radiologist, based on daily consecutive readings of mammograms. First, the films with sufficient and similar image quality were marked, and then further assessed for adequacy of positioning and compression. Adequate positioning was based on the criteria summarized by Eklund et al. (11). Inadequate compression was based on blurring or motion unsharpness, and crowded fibrous structures or ducts on mammograms. All nonqualified images were dismissed from the study so as to obtain a homogeneous group with similar image characteristics.

Dose calculations

Mean glandular dose (MGD) was calculated retrospectively. In order to do this, initially, the entrance skin air kerma (ESAK) was calculated from the post-exposure mAs and previously calculated tube output (mGy/mAs). The ESAK value was distance corrected according to the breast's thickness. Subsequently, MGD was calculated using the ESAK value and G factor. G factor depends on breast thickness as a function of HVL, and is read from the tables (12).

Analysis of data

All data were entered into a database program for analysis (SPSS, v.10.0). Range, mean values, and standard deviations for breast thickness, mAs, and MGD were calculated.

For each film-screen combination, MGDs for thin (<50 mm) and thick (≥50 mm) breasts were compared using Student's t test. For comparisons of film-screen combinations, in terms of MGD, the one-way ANOVA test was used, and the film-screen combinations responsible for significant MGD differences were determined using the least significant difference post-hoc test.

Correlations of mAs and MGD were evaluated with Pearson's correlation coefficient. Comparisons of breast thicknesses, mAs, and MGD in different imaging projections and breast compositions were performed in homogenized subgroups, using the Student's t test.

Results

The mean age was 49.5 years (range, 37–76 years) and the mean thickness of compressed breasts was 50.8 ± 12.2 mm (median, 51 mm; range, 18–78 mm). Of the breasts included in the study, 46% were <50 mm, 29% were 50–59 mm, 18% were 60–69 mm, and 7% were ≥70 mm thick. Breast composition was recorded in 514 breasts. Among these, 315 (61%) were type 1 or 2, and 199 (39%) were type 3 or 4.

The mean kVp used was 27 ± 1.1 (range, 25–30 kVp). In 37% of exposures 26 kVp was used, 27 kVp was used in 33%, and 28 kVp was used in 18% of exposures. Exposure with higher or lower kilovoltage was very rare (9% and 2%, respectively).

MGD in thin breasts was 1.6 ± 0.7 mGy (range, 0.4–3.9 mGy), which was significantly less than that in thick breasts (1.7 ± 0.7 mGy; range, 0.6–4.1) ($P < 0.05$).

Evaluation of the 2 screens with 3 different films showed that at all thicknesses the doses obtained with the Min R 2190 screen were about 50% less than those obtained with the Min R screen (Table 2). Compared to the Min R screen, the Min R 2190 screen provided 52% less dose in thin breasts and 57% less dose in thick breasts when used with Kodak Min R 2000 film. When used with Agfa Mamoray HDR film, these reduction rates were 47% and 52% in thin and thick breasts, respectively. In thin breasts, the lowest doses were obtained with all films combined with the Min R 2190 screen, which were not significantly different from each other ($P > 0.05$) (Table 2). In thick breasts, the lowest dose was obtained with Kodak Min-R S film combined with the Min R 2190 screen ($P < 0.05$). With this film-screen combination the doses in thin and thick breasts were not significantly different from each other ($P > 0.05$) (Table 2). Kodak Min R 2000 and Agfa Mamoray HDR films resulted in similar doses in thin and thick breasts when used with the Min R 2190 screen ($P > 0.05$).

Table 2. Mean glandular dose ± standard deviation (MGD ± SD) values obtained in thin (<50 mm) and thick (≥50 mm) breasts for each film/screen combination

	MGD ± SD (mGy)		
Film/screen	<50 mm	≥50 mm	P^a
Agfa Mamoray HDR/ Kodak Min-R	2.2 ± 0.5	2.4 ± 0.6	<0.05
Kodak Min R-S/Kodak Min R 2190	1.0 ± 0.2	1.0 ± 0.2	>0.05
Kodak Min R 2000/Kodak Min R 2190	0.9 ± 0.2	1.2 ± 0.4	<0.05
Kodak Min R 2000/Kodak Min R	1.9 ± 0.3	2.2 ± 0.6	<0.05
Agfa Mamoray HDR/Kodak Min R 2190	1.1 ± 0.3	1.2 ± 0.3	<0.05
P^b	<0.05	<0.05	

[a]Significance *P* value of Student's t-test.
[b]Significance *P* value of one-way ANOVA.

Table 3. Correlations between mAs and mean glandular dose (MGD) obtained with different film-screen combinations in thin (<50 mm) and thick (≥50 mm) breasts

Film/screen	Thickness (mm)	n	mAs- MGD r[a]	P[b]
Agfa Mamoray HDR/ Kodak Min-R	<50 mm	114	0.880	<0.05
	≥50 mm	77	0.941	<0.05
Kodak Min R-S/Kodak Min R 2190	<50 mm	20	0.975	<0.05
	≥50 mm	28	0.945	<0.05
Kodak Min R 2000/Kodak Min R 2190	<50 mm	31	0.902	<0.05
	≥50 mm	99	0.960	<0.05
Kodak Min R 2000/Kodak Min R	<50 mm	22	0.931	<0.05
	≥50 mm	72	0.959	<0.05
Agfa Mamoray HDR/Kodak Min R 2190	<50 mm	84	0.841	<0.05
	≥50 mm	33	0.873	<0.05

[a]Pearson's correlation coefficient.
[b]Significance *P* value of Pearson's correlation coefficient.

Table 4. Comparisons of breast thickness, mAs, and mean glandular dose (MGD) obtained in craniocaudal (CC) and 45° mediolateral oblique (MLO) imaging projections. Values are mean ± standard deviation (SD).

Projection	n[a]	Thickness (mm)	mAs	MGD (mGy)
CC	37	56.2 ± 4.4	55.3 ± 15.0	1.0 ± 0.2
45° MLO	62	64.2 ± 7.5	87.7 ± 27.2	1.4 ± 0.4
P[b]		<0.05	<0.05	<0.05

[a]Study group: large breasts and Kodak 2000 film/Kodak 2190 screen combination.
[b]Significance *P* value of Student's t test.

Table 5. Comparisons of breast thickness, mAs, and mean glandular dose (MGD) obtained in 45° and 60° mediolateral oblique (MLO) projections. Values are mean ± standard deviation (SD).

MLO angle	n[a]	Thickness (mm)	mAs	MGD (mGy)
45°	42	64.2 ± 10.7	79.1 ± 25.6	1.3 ± 0.3
60°	42	62.2 ± 9.9	71.8 ± 21.3	1.2 ± 0.3
P[b]		<0.05	<0.05	< 0.05

[a]Study group: large breasts and Kodak 2000 film/Kodak 2190 screen combination.
[b]Significance *P* value of Student's t test.

Table 6. Comparisons of breast thickness, mAs, and mean glandular dose (MGD) obtained in predominantly fatty (BI-RADS [Breast Imaging Reporting and Data System] types 1 and 2) and dense (BI-RADS types 3 and 4) breasts. Values are mean ± standard deviation (SD).

Breast composition	n[a]	Thickness (mm)	mAs	MGD (mGy)
Types 1 and 2	92	57.1 ± 10.5	66.0 ± 27.2	± 0.3
Types 3 and 4	26	63.0 ± 9.7	78.6 ± 31.1	± 0.4
P[b]		<0.05	<0.05	<0.05

[a]Study group: large breasts and Kodak 2000 film/Kodak 2190 screen combination.
[b]Significance *P* value of Student's t test.

mAs and MGD were excellently correlated in all film-screen combinations and in all breast thicknesses (r, range, 0.841–0.975) (Table 3). We found weak correlations of mAs and MGD with breast thickness (r, generally lower than 0.400).

Because of the significant dose differences among different film-screen combinations, we evaluated the below mentioned factors by using the data only from one film-screen combination (Kodak Min R 2000/Min R 2190), used with the appropriately selected anode/filter combination.

The mean breast thickness and mAs in 45° MLO view was significantly greater than those in CC view ($P < 0.05$). The dose in 45° MLO view was significantly greater than the dose in CC view (mean ± SD, 1.4 ± 0.4 mGy and 1.0 ± 0.2 mGy, respectively) ($P < 0.05$) (Table 4). Dose differences in CC and 45° MLO views were also significant within the groups of predominantly fatty (types 1 and 2) and dense (types 3 and 4) breasts ($P < 0.05$).

The mean breast thickness and mAs in 60° MLO view were significantly less than those in 45° MLO view ($P < 0.05$). The dose in 60° MLO was significantly less than the dose in 45° MLO (mean ± SD, 1.2 ± 0.3 mGy and 1.3 ± 0.3 mGy, respectively) ($P < 0.05$) (Table 5).

MGD values were significantly higher in BI-RADS (Breast Imaging Reporting and Data System) type 3 and 4 breasts than in type 1 and 2 breasts (mean ± SD, 1.3 ± 0.4 mGy and 1.1 ± 0.3 mGy, respectively) ($P < 0.05$) (Table 6).

Discussion

At the time of this study, we had been using the same equipment (X-ray system, films, screens, processing conditions) and imaging protocol for 5 years, and were considering a replacement of our screens with more sensitive ones in order to reduce the breast dose as much as possible. This study was planned to evaluate the factors affecting breast dose and the accuracy of the variable kVp protocol.

The variable kVp protocol used in this study was shown to be superior to the fixed kVp protocol when both image quality and dose are considered (1, 3, 5, 13). Because the optimal energy is different for breasts of different thickness and composition, a fixed kVp cannot provide the optimal beam quality for all breasts. In breasts ≤50 mm thick

our use of ≤28 kVp with Mo/Mo anode/filter is currently the most appropriate technique to provide maximum contrast (3, 5, 13). In this subgroup, the variable kVp technique has a more significant effect upon image quality than the dose (13). In breasts ≥50 mm thick we used 27–30 kVp with Mo/Rh anode/filter to provide the minimum dose for acceptable image quality. In this subgroup the variable kVp technique has a more significant effect upon dose than image quality (1, 5, 13). However, the doses we obtained in this subgroup were still generally significantly higher than in the <50 mm subgroup (Table 2).

For a number of reasons doses reported from various clinics, even with identical equipment, are difficult to compare. First, technique protocols in mammography differ, not only with the capabilities of the equipment used, but also with preferences of the centers. Despite of the availability of the AOP function, many centers adopt a protocol of a fixed kVp for all or most breast thicknesses (for example, 28 kVp at Mo/Mo) (14), while many others vary kVp according to breast thickness (1, 3, 13). Second, the adaptation of new faster screen-film systems into practice may be considerably problematic. A recent survey shows that, in contrast to expectations, MGD has gradually and significantly increased between 1997 and 2001, which was likely caused by changes in screen-film products and processing techniques, which increased system speed but were used with inappropriately low kVp (7). Finally, dose measurements obtained with 2 methods, the phantom method and the patient method, are usually not comparable, mainly because breast tissue composition complicates the accuracy of dose measurements in the phantom method (5, 13). Contrary to the fact that the relative proportion of adipose tissue increases with breast thickness and age (postmenopausal glandular involution) (15), the reference breast phantom used in dose calculations is typically composed of 50% adipose and 50% glandular-like tissue components. The physiological deviations in breast composition beyond that used in the reference breast phantom have significant effects upon dosimetry evaluations (6, 10, 13, 16–18). One study showed that due to substantial attenuation differences between the standard phantom and real breasts, the phantom method results in 13% overestimation of dose values, by as high as 170% in large breasts (18). Therefore, in contrast to its ease and reproducibility, the widely used phantom method is not as reliable in evaluating the radiation risk as is the patient method, which is why we measured actual breast doses in the present study.

Screen selection is definitely a very important factor affecting the dose, as shown by our finding that the doses obtained with the Min R 2190 screen with 2 different films (Min R 2000 and Agfa Mamoray HDR) were about 50% lower than those obtained with the Min R screen and the same films. This clinical finding is compatible with technical information data stating that with Min R 2000 film, the Min R 2190 screen provides a relative speed of 190, compared to 100 provided by the Min R screen with the same film (Technical Information Data Sheet, Eastman Kodak Company, 2002). Higher dose reduction with the Min R 2190 screen used with Min R 2000 film than with Agfa Mamoray HDR film (52% vs. 47% in thin breasts and 57% vs. 52% in thick breasts) may have been due to less concordance of the Agfa film with the Kodak screen; therefore, of the two, the Min R 2190 screen/Min R 2000 film combination is preferred.

Min R 2000 and Min R-S films, when used with the same screen (Min R 2190), exhibit similar sensitivities (relative speed, 190), according to the technical information data provided by Kodak, which explains our finding of statistically insignificant dose differences with these 2 film/screen combinations in thin breasts. The product data are insufficient to explain the lower doses obtained with Min R-S film in thick breasts, which should be investigated further. For the present, we may assume that these 2 films are equally good alternatives for use with the Min R 2190 screen.

The excellent correlations between mAs and MGD found in our study for all film-screen combinations at all breast thicknesses can be explained by the fact that the dose rises linearly with mAs value, which affects beam quantity (19, 20). Weak correlations of mAs and MGD with breast thickness may be due to the effects of breast composition and relatively smaller increases of mAs occurring at thicknesses >50 mm (19, 20).

The two standard projections in mammography are the MLO and CC views. The angle in the MLO view, however, depends on the anatomic configuration of the patient, and is most often selected as 45°. We found significantly greater MGD in the 45° MLO view than in the CC view. This finding is directly related to greater thickness in the 45° MLO view as compared to the CC view, as well as the greater amount of pectoral muscle and breast tissue included in this view (21). When 2 different angles of MLO (45° and 60°) were compared, the use of the 60° angle resulted in significantly less dose than the 45° angle. This finding is similar to another recent study (22). We agree that the projection of the fibroglandular tissue onto a larger film area in the 60° MLO view results in less superposition of tissues and, therefore, in less thickness and in less dose than in the 45° view. Although standard use of 60° cannot be recommended, it should be preferred to 45° whenever the patient's anatomic configuration is appropriate.

We found significantly higher MGD in dense breasts than in the fatty breasts. Although this may have been due to significantly thicker breasts included in the dense group (Table 6), it was more likely due to higher exposures, i. e., increased penetration needed for dense tissue than for fatty tissue. Although an increase in adipose tissue increases breast thickness (1, 17), it requires less exposure than glandular tissue (11, 16, 17); therefore, selection of exposure factors based only on breast thickness and not breast composition results in unnecessarily high photon energies, which in turn result in substantial contrast reduction.

Although confirming the superiority of the variable kVp technique over the fixed kVp technique, in terms of dose reduction, our study demonstrated the limitation of the variable kVp technique, i. e., semiautomatic mode, by indicating the multiplicity of factors affecting dose, as well as their complex interrelationships that are difficult to control in clinical settings. Proper tailoring of the kVp/anode/filter combination, appropriate screen selection, and well-matched films are mandatory, and considering the use of the 60° imaging angle instead of the 45° for

the MLO view can be useful. However, tailoring of kVp/anode/filter, which should be based on both breast thickness and composition, is difficult to achieve accurately at all times; therefore, the automatic beam quality control mode should replace the semiautomatic mode in screen-film mammography practice, so as to provide easier and more effective control of breast dose and image quality.

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