

Mammography Positioning Standards in the Digital Era: Is the Status Quo Acceptable?

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OBJECTIVE. The objective of our study was to evaluate positioning of full-field digital mammography (FFDM) and digital breast tomosynthesis (DBT) compared with film-screen (FS) mammography positioning standards.

MATERIALS AND METHODS. A retrospective study was conducted of consecutive patients who underwent screening FFDM in 2010–2012 and DBT in 2012–2013 at an academic institution. Examinations were performed by five experienced technologists who underwent updated standardized positioning training. Positioning criteria were assessed by consensus reads among three breast radiologists and compared with FS mammography data from a 1993 study by Bassett and colleagues.

RESULTS. One hundred seventy patients ($n = 340$ examinations) were analyzed, showing significant differences between FFDM and DBT examinations ($p < 0.05$) for medial or inferior skin folds (FFDM vs DBT: craniocaudal [CC] view, 16% [$n = 56$] vs 23% [$n = 77$]); mediolateral oblique [MLO] view, 35% [$n = 118$] vs 45% [$n = 154$]), inclusion of lateral glandular tissue on CC view (FFDM vs DBT, 73% [$n = 247$] vs 81% [$n = 274$]), and concave pectoralis muscle shape (FFDM vs DBT, 36% [$n = 121$] vs 28% [$n = 95$]). In comparison with Bassett et al. data, all positioning criteria for both FFDM and DBT examinations were significantly different ($p < 0.05$). The largest differences were found in visualization of the pectoralis muscle on CC views and the inframammary fold on MLO views, inclusion of posterior or lateral glandular tissue, and inclusion of skin folds, with DBT and FFDM more frequently exhibiting all criteria than originally reported Bassett et al. findings.

CONCLUSION. DBT and FFDM mammograms more frequently include posterior or lateral tissue, the inframammary fold on MLO views, the pectoralis muscle on CC views, and skin folds than FS mammograms. Inclusion of more breast tissue with newer technologies suggests traditional positioning standards, in conjunction with updated standardized positioning training, are still applicable at the expense of including more skin folds.

Keywords: digital breast tomosynthesis, mammography, positioning

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In 2016, more than 246,000 new invasive breast cancers were estimated to be diagnosed in U.S. women, with more than 40,000 women estimated to die of the disease [1]. By detecting cancer early, when treatments are more likely to be effective, screening mammography has shown mortality reductions from breast cancer of up to 63% [2–8]. The success of screening mammography, however, relies on the detection of small and often subtle lesions, which is largely dependent on the quality of images obtained, including breast positioning [9–13]. The importance of breast positioning on the image receptor (IR) has been advocated for decades by radiologists and researchers [10–16], because technical problems and image quality have been

found to be responsible for delayed detection in 22% of screening-detected cancers and 35% of interval breast cancers [17].

Image quality, which is largely controlled by the mammography technologist, influences radiologists' ability to accurately interpret examinations. A recent study of more than 350 mammography technologists showed that the level of training and experience of the technologists and their interactions with radiologists significantly affected radiologists' recall rate, sensitivity, specificity, and cancer detection rate [18]. Failure to obtain proper mammographic positioning can result in exclusion of tissue and, consequently, missed cancers [19]. For example, a study comparing ultrasound to mammography found that 3% of cancers later detected

on ultrasound were not included in the original mammographic images due to difficult anatomic location (i.e., prepectoral location) [10]. Further emphasizing the importance of proper positioning to include as much breast tissue as possible, especially posteriorly, Schrading and Kuhl [20] observed that in women at high risk for breast cancer, including those with *BRCA* mutations, the majority of cancers involved a posterior (i.e., prepectoral) location.

Concerns about the varying quality of mammograms after the advent of modern screening mammography have resulted in various programs and laws attempting to set minimum quality standards to protect public health. The Mammography Quality Standards Act (MQSA) of 1992 was enacted to set federal quality standards for all aspects of mammography [21, 22]. As part of receiving accreditation under MQSA, facilities are evaluated by the American College of Radiology (ACR) on the quality of their clinical images, which includes assessment of breast positioning on mammograms. During evaluation of reasons for failure of mammography units at clinical image review in the ACR Mammography Accreditation Program (MAP), inadequacies in positioning accounted for the failure to achieve accreditation in one of every five reviews [14]. Inadequacies in mammography positioning not only remain a problem in mammography, but also accounted for 92% of deficiencies at the first attempt of mammography accreditation in 2015 [23]. More recently, the U.S. Food and Drug Administration (FDA) has issued a statement citing poor mammography positioning as a cause for most clinical image deficiencies and most failures of accreditation [23].

To improve positioning standards, quality positioning criteria for film-screen (FS) mammography, which were originally reported by Bassett et al. [15] in 1993, were expanded and incorporated into the ACR MAP, including evaluation of visualization of posterior tissue, amount of pectoralis muscle, breast position on IR, skin folds, and inframammary fold, among others [15, 24]. As a result, mammographic positioning has been emphasized at courses teaching updated standardized positioning techniques to optimize visualization of breast tissue and ultimately improve mammographic sensitivity and specificity [25].

Current mammography positioning standards are based on research from 1993 with

FS mammography [15], which has been largely replaced by digital mammography. Full-field digital mammography (FFDM), which first became commercially available in January 2000 [26], now represents more than 76% of total accredited mammography units, and since FDA approval in 2011, 22% of facilities have upgraded to the newest technology, digital breast tomosynthesis (DBT) [27, 28]. These new technologies also have physical differences compared with FS mammography, such as larger detector size and face shields, that can influence patient and breast positioning [29]. For instance, the digital detectors used in DBT acquisition show up to 49% increased length of the Bucky device and IR and an increased thickness of up to 80% when compared with FS cassettes [29]. Face shield requirements have not changed significantly from the transition from FS mammography to FFDM, but face shields have increased in width up to 50% for DBT units to accommodate tube movement [29]. The timing of the recent FDA report on mammography positioning deficiencies [23] and advent of these newer digital technologies may sug-

gest that changes in the sizes of digital detectors and face shields could be associated with positioning failures.

However, few data exist about how newer technologies affect currently accepted clinical evaluation of positioning standards. As more patients elect to undergo DBT evaluation, maintaining quality positioning will be necessary to detect early-stage breast cancer. To ensure mammographic quality and compliance with MQSA standards, it is important to explore whether the thicker detectors impact mammographic positioning through further evaluation of positioning criteria for FFDM and DBT images. Given these significant changes in detector size and the potential impact on positioning and mammographic image quality, an updated, standardized mammography positioning training has been developed to address these changes. Using direct visual comparison of mammographic positioning on FFDM and DBT images, this study evaluated the applicability of updated positioning training and compared the results with previous positioning standards originally intended for FS images to FFDM and DBT units.

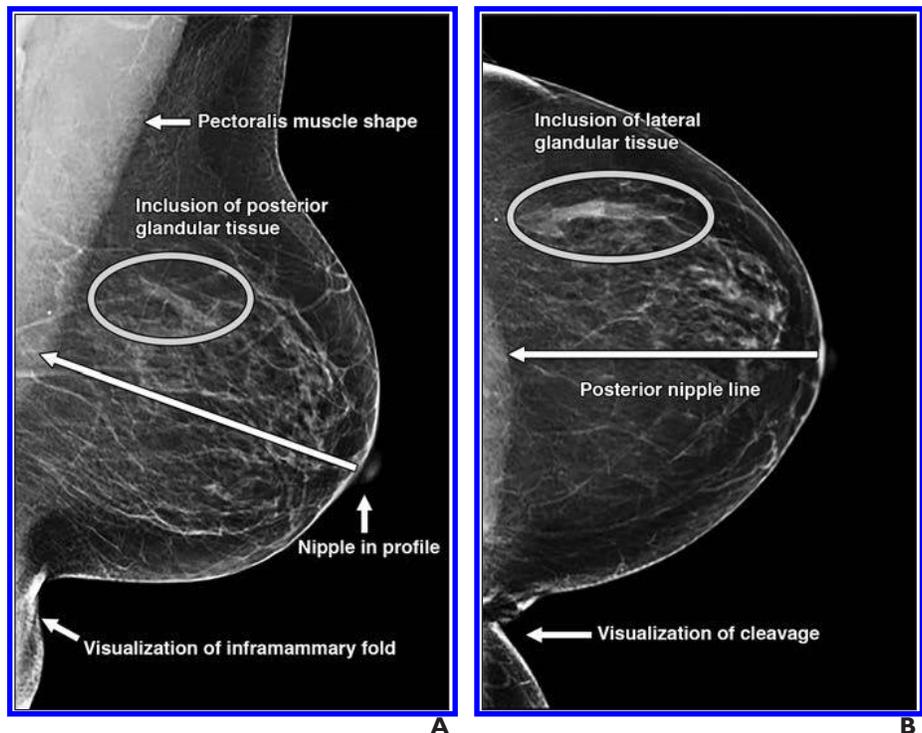


Fig. 1—Illustrations of selected mammography positioning criteria. **A** and **B**, Mediolateral oblique (**A**) and craniocaudal (**B**) mammographic views of 55-year-old woman show examples of several standard positioning criteria, as originally evaluated by Bassett et al. [15]. In addition, presence or absence of motion, presence and location of skin or fat folds, and whether more than one view was necessary to include all tissue adequately were assessed. Ovals show glandular tissue, and long arrow in **A** shows posterior nipple line.

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Materials and Methods

A retrospective study was conducted of a cohort of women, 30 years old or older, with one or more bilateral FFDM screening examinations between December 1, 2010, and February 28, 2012, and one or more bilateral DBT screening examinations between March 1, 2012, and August 31, 2013, at a tertiary care academic institution's breast imaging center. DBT examinations were performed according to FDA-approved methods (i.e., combined conventional FFDM and DBT); however, only the conventional FFDM images were included for review. This study was HIPAA compliant, and institutional review board approval was obtained to review patient records.

All patients with both FFDM and DBT examinations performed at our institution by one of five mammography technologists were included. Each of these technologists had more than 10 years of experience and had participated in updated standardized positioning training for newer FFDM and DBT technologies in November 2010 by a positioning expert. This positioning training primarily focused on the following challenges presented by the new digital technologies [1]: overcoming the loss of medial and posterior tissue on the craniocaudal (CC) view due to the larger face shield by strictly positioning from the medial side of the breast, using both hands to pull the breast onto the IR and setting the proper height of the IR, and reducing axillary folds and ensuring inclusion of sufficient inframammary fold by focusing attention on the placement of the IR in the axilla and making changes in patient position. Patients were excluded if they had a prior lumpectomy or mastectomy, had a breast implant, had undergone breast reduction between the two examinations, or had any significant physical limitation as noted by the mammography technologist in the electronic medical record. Patients meeting the inclusion criteria were identified through our institution's electronic medical record using Current Procedural Terminology codes to select desired examinations within the specified dates. FFDM units (Selenia Dimensions, Hologic) were installed in August 2007 with a DBT upgrade of two of the three available units in February 2012. Patients choosing to undergo DBT were required to pay an additional cost (\$60) if DBT was not covered by their insurance.

Both mammographic studies of each patient were evaluated in a categoric manner as to whether or not they met multiple positioning criteria and were then compared with the published bilateral FS mammography data from the positioning study by Bassett et al. [15]. Consensus reads among three investigators (two board-certified full-time breast radiology staff and one breast radiology

fellow) were used to evaluate CC and mediolateral oblique (MLO) views from both the FFDM and DBT examinations. For each patient, FFDM mammograms were reviewed first, followed by DBT mammograms. Consensus reads were obtained among all three readers for each case, with all three or two of the three readers initially agreeing about nearly all cases. If a full consensus was not reached, each case was discussed until all three readers agreed.

In addition to measuring the posterior nipple line (PNL) and compression force, the following criteria were evaluated for each examination: visualization of the pectoralis muscle extending to the PNL on the MLO view, the shape of the pectoralis muscle, presence of a wide margin at the

top of the pectoralis muscle, visualization of the pectoralis muscle on the CC view, presence or absence of motion, presence of nipple in profile, presence and location of skin or fat folds, visualization of the inframammary fold, visualization of cleavage, inclusion of all lateral (on CC view) or posterior (on MLO view) glandular tissue, and whether more than one view was necessary to include all tissue adequately (Fig. 1). Z-tests were used to test for differences in the proportion of bilateral examinations meeting positioning criteria for FFDM, DBT, and FS mammography modalities. Statistical analyses were performed using statistical software (SPSS, version 22.0, IBM), and statistical significance was determined using a p value < 0.05 .

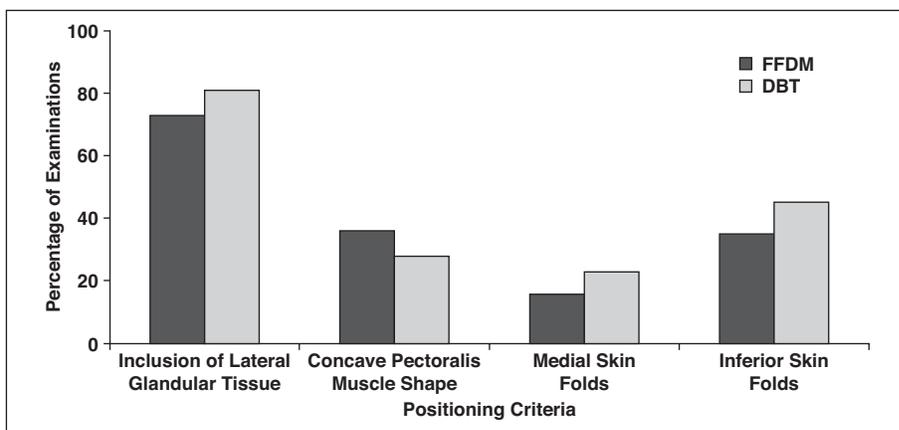


Fig. 2—Bar graph depicts four positioning criteria that showed statistically significant differences between full-field digital mammography (FFDM) and digital breast tomosynthesis (DBT).

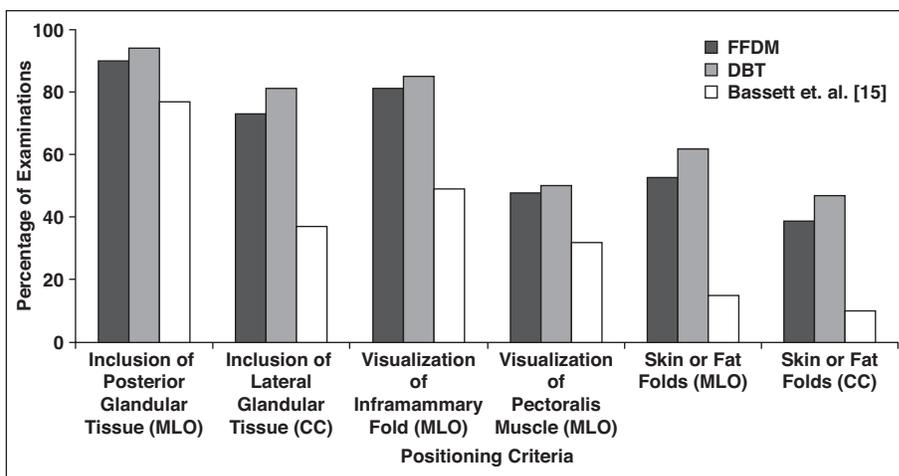


Fig. 3—Bar graph shows significant differences in proportion of film-screen (FS) mammography (Bassett et al. [15]), full-field digital mammography (FFDM), and digital breast tomosynthesis (DBT) examinations exhibiting positioning criteria ($p < 0.05$). Although all positioning criteria for both FFDM and DBT examinations showed significance ($p < 0.05$) when compared with Bassett et al. [15] data, largest differences were seen in six criteria shown on bar graph. There was inclusion of more breast tissue in FFDM and DBT examinations than in FS mammography examinations, as shown by improvement in first four criteria; however, inclusion of more breast tissue was at expense of including more skin or fat folds on both views. CC = craniocaudal, MLO = mediolateral oblique.

TABLE 1: Age and BI-RADS Density Category of 170 Patients in Study Group

Characteristic	Value
Age at examination (y), mean (SD)	
FFDM, mean (SD)	57.9 (10.61)
DBT, mean (SD)	59.4 (10.54)
BI-RADS density category, no. (%) of patients	
A or B	61 (35.9)
C or D	109 (64.1)

Note—FFDM = full-field digital mammography, DBT = digital breast tomosynthesis.

Results

Of the 208 consecutive female patients who underwent both FFDM and DBT during the study time frame, 170 patients ($n = 340$ examinations) met the inclusion criteria. The age of study participants ranged from 36 to 91 years, with a mean age of 57.9 years (SD = 10.61) for FFDM examinations and 59.4 years (SD = 10.54) for DBT examinations (Table 1). In nearly two-thirds (64.1%) of patients, breast tissue density was heterogeneously dense or extremely dense.

Compression force and PNL measurements were evaluated for both modalities in each of the standard views, with no significant differences found (Table 2). For the MLO view, the mean compression force

TABLE 2: Compression Force and Posterior Nipple Line Measurements in 170 Patients in Study Group

Characteristic	FFDM ($n = 170$)	DBT ($n = 170$)
Compression force (N), mean (SD)		
MLO, mean (SD)	22.8 (6.61)	21.4 (6.00)
CC, mean (SD)	19.4 (4.63)	18.8 (5.07)
Posterior nipple line measurement < 1 cm difference between MLO and CC views, no. (%) of patients		
Right breast	154 (90.6)	156 (91.8)
Left breast	161 (94.7)	155 (91.2)

Note—FFDM = full-field digital mammography, DBT = digital breast tomosynthesis, MLO = mediolateral oblique, CC = craniocaudal.

used was 22.8 N in FFDM compared with 21.4 N in DBT. For the CC view, the mean compression force was 19.4 N in FFDM compared with 18.8 N in DBT. There were no significant differences in the proportion of mammograms with a less-than-1-cm difference in PNL measurements between the MLO and CC views when comparing both modalities (right and left breasts: FFDM, 91% [$n = 154$] and 95% [$n = 161$]; DBT, 92% [$n = 156$] and 91% [$n = 155$]). However, a significantly smaller proportion of FS mammograms in the Bassett et al. study [15] had a less-than-1-cm difference in the PNL between MLO and CC views ($p < 0.05$).

Results showed statistically significant differences ($p < 0.05$) in the proportion of FFDM and DBT examinations exhibiting inclusion of

lateral glandular tissue on the CC view (FFDM vs DBT: 73% [$n = 247$] vs 81% [$n = 274$]), concave pectoralis muscle shape (FFDM vs DBT: 36% [$n = 121$] vs 28% [$n = 95$]), and medial and inferior skin folds (FFDM vs DBT: CC, 16% [$n = 56$] vs 23% [$n = 77$]; MLO, 35% [$n = 118$] vs 45% [$n = 154$]) (Fig. 2). No significant differences were found between FFDM and DBT examinations for the following criteria: visualization of the pectoralis muscle to the PNL, wide margin at the top of the pectoralis muscle, nipple in profile, requiring more than one view, motion present, superior MLO and lateral CC skin folds, visualization of the pectoralis muscle and cleavage on the CC view, and visualization of the inframammary fold and inclusion of posterior glandular tissue on the MLO view (Table 3).

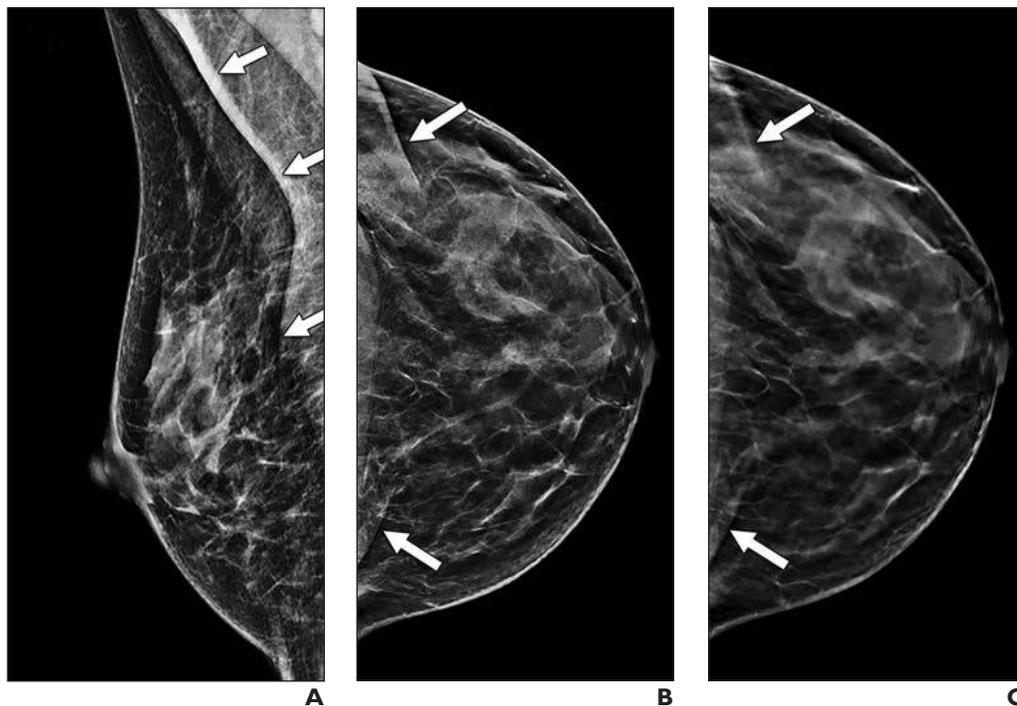


Fig. 4—Examples of skin folds included in digital breast tomosynthesis (DBT) images of 48-year-old woman. Some positioning criteria were noted to be more subjective in nature, including skin folds. However, skin folds were often seen most in areas where only fatty tissue was present. Additionally, skin folds would be detected on only first and last few slices of DBT examinations and thus would be unlikely to interfere with examination interpretation.
A, Example of skin fold (arrows) on edge of DBT image that does not significantly compromise evaluation of fibroglandular tissue.
B, Synthesized 2D mammography image from DBT examination shows skin folds (arrows).
C, Skin folds (arrows) become less conspicuous when viewing DBT images.

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In comparison with the Bassett et al. [15] data, significance ($p < 0.05$) was shown for all positioning criteria for both FFDM and DBT examinations. However, the largest differences were found in the proportion of examinations exhibiting inclusion of the posterior and lateral glandular tissue, inclusion of the inframammary fold on the MLO view, visualization of the pectoralis muscle on the CC view, and visualization of skin or fat folds, with DBT and FFDM examinations more frequently exhibiting all criteria (Fig. 3).

Discussion

In our retrospective evaluation of positioning criteria of both FFDM and DBT mammograms, we found a significant improvement in the frequency of examinations exhibiting acceptable positioning criteria, as compared with original FS mammography data in the Bassett et al. [15] study. Statistically significant differences were observed in the comparison of FFDM and DBT mammograms, primarily improvement in inclusion of lateral and posterior tissue on DBT examinations compared with FFDM examinations, with the limitation of increased numbers of patients with a concave shape of the pectoralis muscle and medial or inferior skin folds. Improved positioning techniques also resulted in the visualization of more posterior breast tissue, where most skin folds are located.

Our results differ from those of the original Bassett et al. [15] FS mammography study in two key ways. First, we observed more skin folds, which is likely because of the increased size of digital detectors compared with film detectors. Although there were significantly more skin folds on DBT examinations, there was not a significant increase in the number of repeat images, which suggests satisfactory image quality for radiologist interpretation. In our study, skin folds were often observed at the edge of the images near the axilla or inframammary fold where only fatty tissue was present (Fig. 4). Additionally, regardless of skin fold position on the conventional FFDM images, skin folds are more easily characterized on DBT images because they would be detected on only the first and last few slices and thus would not interfere with examination interpretation (Fig. 4).

Second, the observed increase in posterior and lateral tissue on FFDM and DBT examinations suggests that the FS mammography standards in the Bassett et al. [15] study can be improved. This may be because mammography positioning is a learned skill rein-

TABLE 3: Proportions of Full-Field Digital Mammography (FFDM) and Digital Breast Tomosynthesis (DBT) Examinations Exhibiting Positioning Criteria Compared With the Original 1993 Bassett et al. [15] Positioning Study

Positioning Criteria	Percentage of Examinations		
	FFDM	DBT	Bassett et al. [15]
MLO view			
Visualization of pectoralis muscle to posterior nipple line	86	87	81
Concave pectoralis muscle	36	28	—
Straight pectoralis muscle	41	46	—
Convex pectoralis muscle	23	26	—
Wide margin at top of pectoralis muscle	95	93	—
No motion	98	97	99
Posterior glandular tissue included	90	94	77
Nipple visible in profile	89	92	88
Skin or fat folds included	53	62	15
Upper location of skin or fat folds	25	27	—
Lower location of skin or fat folds	35	45	—
Visualization of inframammary fold	81	85	49
Requires more than one view	13	17	—
CC view			
Pectoralis muscle visualized	48	50	32
No motion	100	98	—
Lateral glandular tissue included	73	81	37
Nipple visible in profile	83	85	89
Skin or fat folds included	39	47	10
Medial location of skin or fat folds	16	23	—
Lateral location of skin or fat folds	29	32	—
Visualization of cleavage	41	34	—
Requires more than one view	5	7	—

Note—Dash (—) indicates criteria that were not measured in Bassett et al. [15] study. MLO = mediolateral oblique, CC = craniocaudal.

forced through continual education and self-improvement. Moreover, increases in the size of image detectors and face shields present technical challenges that may not negatively affect positioning, given the improvements shown in our study as compared with the Bassett et al. data. In this study, the five technologists had many years of mammography experience, had formal continuing education, and had participated in an onsite training using updated standardized positioning skills to address equipment modifications with a nationally recognized mammography positioning expert.

The Bassett et al. [15] study compared images and established image quality criteria using pre- and poststandardized positioning training, which showed an overall improve-

ment in image quality by 68% when technologists applied standardized techniques. Although imaging technology has continued to evolve and IRs and face shields have increased in size, our study suggests that the Bassett et al. positioning criteria can be improved on despite challenges presented by newer technologies. Future research should assess performance changes as a result of positioning training and perhaps whether various training methods have similar or different outcomes. Although the FDA has cited poor positioning as being responsible for most accreditation failures, it is notable that MQSA regulations do not mandate hands-on positioning training for the initial required 40 hours of mammography technologist education or the 15 hours of continuing edu-

cation required every 3 years to receive or maintain MQSA certification [30].

Since Bassett et al. [15] reported that standardized positioning of mammography techniques improves image quality, a major strength of the current study is that all technologists not only were trained according to standardized positioning techniques, but also received updated positioning training to address challenges due to larger and thicker detectors. Breast imaging practices and patients also benefit from training staff receives in updated standardized positioning techniques because it results in mammographic studies that are more consistent, reproducible, and more often meet clinical image evaluation criteria. The resulting improved images also facilitate comparison from year to year, thereby decreasing unnecessary patient callbacks.

Our study also has several limitations. First, we had a smaller number of patients than the original Bassett et al. [15] study (170 vs 1000 patients, respectively) because all patients in our study were required to have both FFDM and DBT examinations performed only by technologists who completed standardized mammography positioning training by the same expert. As a result, all differences between our study and the Bassett et al. study were statistically significant due to differences in sample sizes. However, we chose to focus our discussion on the largest and most clinically meaningful differences. Second, our results may not translate to other centers that receive different curriculum or educators for mammography positioning, but applicability could be assessed by further research at other facilities that undertake different training approaches. Third, this study was performed with only Hologic mammography units, which may limit the generalizability of findings to units made by other manufacturers.

Fourth, our study included a higher percentage of patients with dense breasts compared with typically reported populations (64.1% in our study vs 50% in other reported populations) [31]. This difference may be because our facility has an active high-risk clinic that targets patients with dense breasts. Fifth, patients may have self-selected to undergo DBT rather than FFDM examinations because there was an additional cost potentially associated with DBT. Theoretically, there is potential for selection bias; however, this is unlikely because patients were unaware of the physical differences in the detector sizes.

Finally, it was difficult to define objective criteria for positioning parameters that are more subjective in nature. For example, inclusion of the pectoralis muscle and the shape of the pectoralis muscle had little, if any, disagreement among observers. However, other parameters, such as satisfactory inclusion of the inframammary fold or what types of images showed a significant undesirable fold, were more subjective in nature (Fig. 4). To ensure consistency, the three readers agreed on the same approach to evaluate all FFDM and DBT images and used a consensus reads process.

In summary, our study suggests that despite limitations inherent in newer digital technologies, traditional positioning standards based on FS mammography can be improved with updated training that addresses the differences in equipment. These findings are significant for radiologists because suboptimal breast positioning is known to result in missed cancers at screening mammography, as well as to contribute to most accreditation failures. The clinical implications of our findings are that changes inherent in these new digital technologies should not be a significant limitation in positioning or result in accreditation failure. Future research should focus on directly assessing whether updated mammography positioning training improves positioning skills.

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