Radiology

ORIGINAL RESEARCH • BREAST IMAGING

Breast Cancer Conspicuity on Simultaneously Acquired Digital Mammographic Images versus Digital Breast Tomosynthesis Images

Katrina E. Korhonen, MD • Emily F. Conant, MD • Eric A. Cohen, MS • Marie Synnestvedt, PhD • Elizabeth S. McDonald, MD, PhD • Susan P. Weinstein, MD

From the Department of Radiology, Division of Breast Imaging, Hospital of the University of Pennsylvania, 3400 Spruce St, 1 Silverstein, Philadelphia, PA 19104. Received September 3, 2018; revision requested October 15; revision received March 28, 2019; accepted April 2. **Address correspondence to** K.E.K. (e-mail: *Katrina.Korhonen@uphs.upenn.edu*).

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Background: Digital breast tomosynthesis (DBT) has been shown to improve screening outcomes compared with digital mammography (DM) alone. However, little is known about differences in breast cancer conspicuity between DM and DBT or by mammographic view.

Purpose: To compare conspicuity of breast cancers at DM versus DBT and by mammographic view, craniocaudal (CC) versus mediolateral oblique (MLO).

Materials and Methods: Lesion conspicuity was graded by three readers by using a 0–5 numerical scale on both DM and DBT images from combined DM and DBT studies for 197 consecutive screening-detected cancers in women (mean age, 60.4 years ± 11.1 [standard deviation]) from October 1, 2011, through December 31, 2014. Intermodality (ie, DM vs DBT) and intramodality (ie, CC vs MLO) analyses were performed. For intramodality analyses, conspicuity was analyzed by view, CC versus MLO, within the same modality. Conspicuity grades were dichotomized into low (scores 0–3) and high (scores 4 and 5) conspicuity. This binary result was assessed by using a generalized linear mixed-effects model with logit link function, random-effect intercept for reader, and compound symmetry covariance structure for lesion.

Results: Cancers were more likely to be high conspicuity at DBT than at DM (odds ratio [OR], 2.4; 95% confidence interval [CI]: 1.9, 3.0; $P < .01$). At both DM and DBT, cancers were more likely to be high conspicuity at the CC than the MLO view (DM vs DBT OR, 1.6 [95% CI: 1.3, 1.9] vs 1.7 [95% CI: 1.3, 2.1], respectively; $P < .01$ for both). Cancers seen at one view only were more often detected at CC than MLO for both DM and DBT (DM vs DBT OR, 1.6 [95% CI: 1.2, 2.0] vs 3.6 [95% CI: 1.9, 7.0], respectively; $P < .01$.).

Conclusion: Cancers were more conspicuous at digital breast tomosynthesis than at digital mammography. Cancers may only be detected at one of two views, and they are more likely to be seen at the craniocaudal view.

Mammography is the standard of care for breast cancer screening despite its limitations in specificity and sensitivity. At digital mammography (DM), the planar, two-dimensional image acquisition can result in both false-positive and false-negative findings because of superimposition and overlapping breast tissue. The majority of studies that assessed the screening outcomes of digital breast tomosynthesis (DBT) compared with screening at DM alone have shown a reduction in false-positive findings coupled with an improvement in cancer detection rates, although a few studies have reported either a nonsignificant increase in cancer detection rate or a slight decrease in cancer detection rate (1–6). Skaane et al (2) demonstrated a 15% reduction in false-positive results and a 27% increase in cancer detection rates with DBT compared with screening with DM alone. Friedewald et al (1) demonstrated a 15% recall reduction and a 41% increase in cancer detection rate by using DBT with DM compared with DM alone. Similarly, McCarthy et al (3) reported a recall reduction of 15% and a 19.6% increase in cancer detection rate in patients who underwent combination DBT with DM screening compared with DM alone.

The reconstructed image stack and angular acquisition of DBT images allow for better viewing of subtle lesions and lesion margins by reducing the effect of overlapping breast tissue. Although multiple studies have reported improvements in cancer detection rate with DBT (1–4,6,7), little is known about lesion conspicuity by mammographic view (8,9). Rafferty and colleagues (9) reported in an analysis of 34 lesions that 27% of the lesions were better observed at one view, with 9% visible at only one view. Similar results were reported by Beck et al (8), wherein 39% of the lesions were better observed at one view and 7% were observed only at one view.

Despite these reports that suggest that some cancers are observed only at one view, the use of one-view-only DBT has been explored (10). Lång et al (10) suggested that one-view DBT could be a feasible stand-alone screening

Abbreviations

CC = craniocaudal, CI = confidence interval, DBT = digital breast tomosynthesis, DM = digital mammography, MLO = mediolateral oblique, OR = odds ratio

Summary

For cancers visible at only one mammographic view, they are more often seen at the craniocaudal view than the mediolateral oblique view for both digital mammography and digital breast tomosynthesis.

Key Points

- Breast cancers were likely to be more conspicuous at digital breast tomosynthesis (DBT) than digital mammography (DM; odds ratio [OR], 2.4; $P < .01$).
- With a narrow angle DBT system, cancers may be better seen or only seen at one of the two DBT views; therefore, a two-view DBT study is optimal.
- For both DM and DBT, if cancers are seen only at one of two views, they are more likely to be visible at the CC view than on the MLO view (DM vs DBT OR, 1.6 vs 1.7; $P < .01$ for both).

Table 1: Population Characteristics

Parameter	No. of Patients
BI-RADS density category	
a	16 (8.1)
b	106 (53.8)
c	72 (36.5)
d	3 (1.5)
Cancer type	
Invasive carcinomas	140 (71.1)
Ductal carcinoma in situ	57 (28.9)

Note.—Data in parentheses are percentages. Mean patient age was 60.4 years ± 11.1 (median, 60.5 years; interquartile range, 51.2–68.7; age range, 37.7–88.7 years). Breast Imaging and Data System scoring is as follows: a, almost entirely fatty; b, scattered fibroglandular density; c, heterogeneously dense; and d, extremely dense. There were 197 cancers imaged. BI-RADS = Breast Imaging Reporting and Data System.

modality because the cancer detection rate on mediolateral oblique (MLO)–only DBT images was significantly better than on two-view DM images. Multiple studies have demonstrated that one-view MLO DBT is noninferior or even superior to two-view DM screening (11–14).

Although the one-view DBT reduces radiation dose, there is concern that sensitivity and specificity of screening with a single view are inferior to two-view DBT screening (11,12,15). To this aim, we sought to assess the conspicuity of consecutive screening-detected cancers from a population-based DM with DBT screening program. The cancer conspicuity by modality (DM vs DBT) and by view (craniocaudal [CC] vs MLO) within each modality was compared to understand the added value of two-view DBT screening.

Materials and Methods

Study Population

This retrospective study was Health Insurance Portability and Accountability Act compliant and approved by the institutional review board. Written informed consent was waived because of the retrospective nature of this study. There was no industry support for this study. Although one author (E.F.C.) has a grant from and was a consultant for Hologic, the data set was not controlled by this author. Our study period started when we began screening all patients by using combined DM and DBT and ended when our institution stopped combined DM and DBT screening in favor of DBT-only screening along with synthesized two-dimensional mammographic (c-view) images. From October 1, 2011, through December 31, 2014, there were 38 332 consecutive screening events that helped to detect 197 consecutive patients with pathologic analysis–proven breast cancer. We excluded patients who presented for diagnostic mammography, interval cancers, and cancers that were occult at mammography. All patients underwent combined DBT and DM screening per a U.S. Food and Drug Administration–approved protocol (Dimension; Hologic, Bedford, Mass). Electronic medical records were used to document patient demographics including age, Breast Imaging Reporting and Data System breast density and overall assessments, imaging reports, and pathologic results. Patient characteristics and breast density are reported in Table 1.

Image Interpretation

Three fellowship-trained breast imagers (E.S.M., with 4 years of experience, S.P.W., with 15 years of experience, and E.F.C., with 23 years of experience) reviewed and graded the conspicuity of cancers at both DM and DBT. The readers were provided with the location (clock-face location and distance from the nipple) and lesion type (calcifications, architectural distortion, mass, or a combination) at the time of review. This ensured that the correct lesion was evaluated because the study goal was to grade lesion conspicuity, not evaluate lesion detection. Query of the electronic medical record was not permitted. The readers graded the entire DM image set followed by the DBT image set in a fixed order. Side-by-side comparison of the two modalities was not permitted. Readers were not permitted to discuss patients or access other readers' results. There was no mandatory lag time between DM and DBT interpretations. All images were viewed by using a dedicated research computer, and data were collected electronically by using software (RedCap version 6.5; Vanderbilt University, Nashville, Tenn) (16).

Cancer conspicuity was graded by each reader on a six-point scale (from 0 to 5) for the modality overall (DM and DBT) and by each mammographic view (CC and MLO). All readers underwent training by using the grading scale before interpreting images, and they had access to the text reference scale and the reference images available on the dedicated research computer while grading. The numerical scale was as follows: 0, not seen (the reader cannot identify the abnormality despite knowing its location); 1, seen only in retrospect (the reader would not have prospectively identified the abnormality but can do so knowing its location); 2, very subtle; 3, subtle; 4, seen; and 5, clearly seen.

Each interpretation (one image set, both CC and MLO views, at one modality, by one reader) served as the unit of

Table 2: Sample Sizes for Complete Data Set and Subsets by Cancer Type and View

Comparison	Sample Size (Interpretations)	Cancers
By modality (DBT vs DM)		
DBT versus DM overall, all cancers	1182	197 cancers*
DBT versus DM, CC view, all cancers	1104	184 cancers in-field on CC view*
DBT versus DM, MLO view, all cancers	1128	188 cancers in-field on MLO view*
DBT versus DM overall, invasive cancers only	840	140 invasive cancers*
DBT versus DM, CC view, invasive cancers only	780	130 invasive cancers in-field on CC view*
DBT versus DM, MLO view, invasive cancers only	792	132 invasive cancers in-field on MLO view*
By view (CC vs MLO)		
CC versus MLO, DBT, all cancers	1050	175 cancers in-field on both views†
CC versus MLO, DM, all cancers		
CC versus MLO, DBT, invasive cancers only	732	122 invasive cancers in-field on both views†
CC versus MLO, DM, invasive cancers only		

Note.—There were 197 cancers and 140 invasive cancers. The unit of analysis is the reader interpretation, and sample sizes vary by comparison. CC = craniocaudal, DBT = digital breast tomosynthesis, DM = digital mammography, MLO = mediolateral oblique.

* Each cancer was interpreted by using two modalities by each of the three readers for a total of six data points for every cancer.

† Each cancer was interpreted at two views by each of the three readers for a total of six data points for every cancer.

Table 3: Odds of High Conspicuity and Odds of Visibility according to Modality

	All Views*		CC View†		MLO View‡	
Parameter	Odds Ratio	*P* Value	Odds Ratio	*P* Value	Odds Ratio	*P* Value
Odds of high conspicuity						
All cancers						
DM	…	…	…	…	…	…
DBT	2.4 (1.9, 3.0) [0.35, 0.36]	<.01	2.7 (2.1, 3.4) [0.22, 0.23]	<.01	2.2 (1.8, 2.6) [0.06, 0.07]	<.01
Invasive cancers						
DM	…	…	…	…	…	…
DBT	3.1 (2.3, 4.2) [0.40, 0.42]	<.01	3.5 (2.6, 4.8) [0.24, 0.26]	<.01	2.7 (2.2, 3.5) [0.12, 0.13]	<.01
Odds of visibility						
All cancers						
DM	…	…	…	…	…	…
DBT	5.4 (2.8, 10.5) [0.18, 0.22]	<.01	7.6 (3.8, 15.1) [0.11, 0.14]	<.01	2.9 (2.0, 4.0) [0.03, 0.05]	<.01
Invasive cancers						
DM	…	…	…	…	…	…
DBT	5.2 (2.5, 10.7) [0.25, 0.29]	<.01	6.9 (3.2, 15.2) [0.18, 0.23]	<.01	4.1 (2.6, 6.4) [0, NA]	<.01

Note.— Data in parentheses are 95% confidence intervals; data in brackets are variance of random-effect reader intercepts and standard error of reader intercepts (logit scale). High conspicuity was considered to be grades 4 or 5, whereas odds of visibility used grades 2–5. CC = craniocaudal, DBT = digital breast tomosynthesis, DM = digital mammography, MLO = mediolateral oblique, NA = not applicable.

* All cancers: 197 cancers (1182 interpretations). Invasive cancers: 140 invasive cancers (840 interpretations).

† All cancers: 184 cancers in-field at CC view (1104 interpretations). Invasive cancers: 130 invasive cancers in-field at CC view (780 interpretations).

‡ All cancers: 188 cancers in-field at MLO view (1128 interpretations). Invasive cancers: 132 invasive cancers in-field at MLO view (792 interpretations).

analysis. Each image set, evaluated by each of the three readers, was a separate data point; no consensus or summarization was involved.

Statistical Analysis

Conspicuity measures were compared across modalities overall and according to view, as follows: DBT overall versus DM overall, CC DBT versus CC DM, and MLO DBT versus MLO DM. Intramodality cancer conspicuity was assessed by view, as follows: CC DBT versus MLO DBT and CC DM versus MLO DM. Table 2 lists the number of cancers and sample sizes.

For the initial data set of 197 cancers, each case contributed two sets of images (DM both views and DBT both views). Each image set was interpreted by three readers, which resulted in 1182 data points (six interpretations × 197 cancers). A subgroup analysis of conspicuity was also performed for invasive cancers (n = 140), excluding 57 cases of ductal carcinoma in situ. A

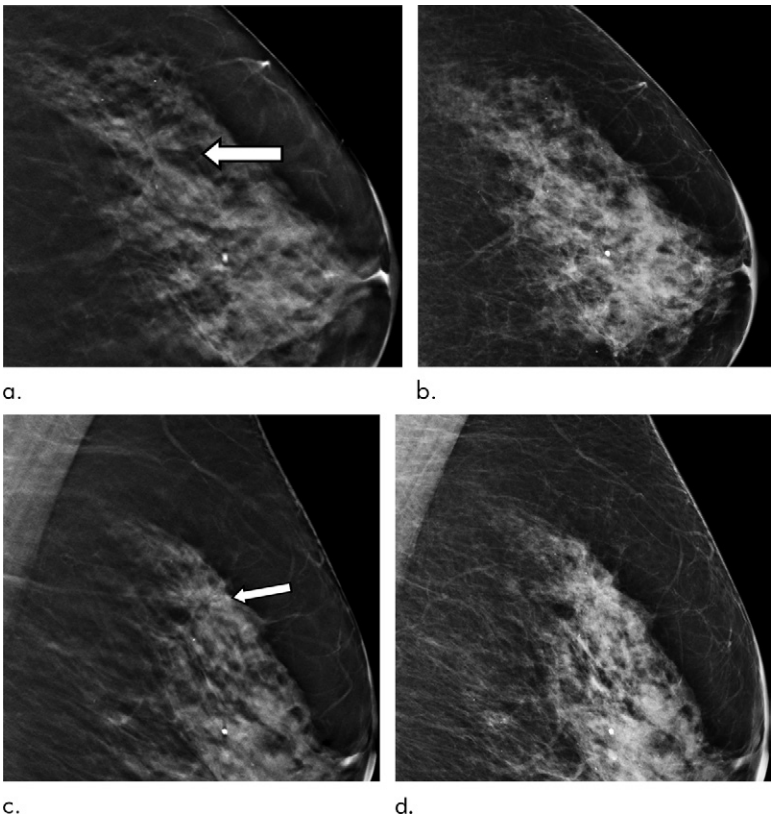


Figure 1: Images in a 68-year-old woman with invasive ductal cancer seen only at digital breast tomosynthesis (DBT). Architectural distortion (arrow) is seen in the upper outer breast on the **(a)** craniocaudal (CC) DBT image and **(c)** mediolateral oblique (MLO) DBT image. The distortion is not seen at **(b)** digital mammography (DM) CC or **(d)** MLO DM views.

subgroup analysis that excluded ductal carcinoma in situ–only cases was performed because ductal carcinoma in situ most commonly manifests as calcifications, which are assessed by both morphologic appearance and distribution. Because distribution information may be difficult to ascertain on the basis of the individual sections at DBT, a subgroup analysis of invasive cancers was also performed. There were 840 data points (six interpretations × 140 cancers) for the analysis of the 140 invasive cancers. For analyses involving one view and for analyses comparing views, sample sizes were smaller to account for lesions that were out of field at one of the views (Table 2). A lesion was considered out of the field of view if it was only partially imaged or not imaged at all at one of the two views because of patient positioning or anatomic location of the abnormality precluding its inclusion on both images.

For conspicuity analysis, the results were dichotomized into low (score of 0–3) and high (score of 4 and 5) conspicuity. For the visibility analysis, conspicuity was dichotomized into seen (scores 2–5) and not seen (scores 0 and 1). The repeated-measurements nature of the study (ie, the same reader evaluating multiple images and the same images evaluated by multiple readers) meant that more straightforward measures, the proportion of high versus low conspicuity interpretations, and the proportion of seen versus not seen could not yield accurate *P* values and confidence intervals (CIs). Rather, a generalized linear mixed-effects model was used that could provide odds ratios (ORs) for chance of high versus low conspicuity and for chance of seen versus not seen. The generalized linear mixed-effects model used a logit link function. Readers were modeled with random-effects intercepts and lesions were modeled with a compound symmetry covariance structure. Interrater agreement regarding conspicuity and visibility was evaluated by using Fleiss κ, which tested the degree to which readers' assessments of visibility and conspicuity were greater than those expected by chance (17).

A *P* value less than .05 was used throughout to indicate statistical significance. Statistical analysis was performed with software (SAS software version 9.4, SAS Institute, Cary, NC; proc GLIMMIX, R version 3.5.1, R Foundation for Statistical Computing, Vienna, Austria, *http://www.r-project.org*; tidyverse, R Foundation for Statistical Computing, *https://cran.r-project.org/package=tidyverse*; and raters, R Foundation for Statistical Computing, *https://CRAN.R-project.org/package=raters*).

Results

From October 1, 2011, through December 31, 2014, there were 197 consecutive screening-detected cancers in female patients (mean age, 60.4 years ± 11.1 [standard deviation]). Breast density distribution was as follows: almost entirely fatty, 8.1% (16 of 197); scattered fibroglandular, 53.8% (106 of 197); heterogeneously dense, 36.5% (72 of 197); and extremely dense, 1.5% (three of 197).

Table 3 shows comparisons of conspicuity assessments across modalities, DBT versus DM for all cancers with subgroup analysis for invasive cancers only. For all cancers, cancers were more likely to have high conspicuity on DBT images than on DM images (OR, 2.4; 95% CI: 1.9, 3.0; $P < .01$). This is also true for conspicuity across modalities at the same mammographic view (CC DBT vs CC DM and MLO DBT vs MLO DM) because cancers were more likely to have high conspicuity on DBT images compared with the same view on DM images (CC vs MLO OR, 2.7 [95% CI: 2.1, 3.4] vs 2.2 [95% CI: 1.8, 2.6], respectively; $P < .01$ for both). In the subgroup conspicuity analysis of invasive carcinomas, higher ORs were also observed at DBT. Figure 1 demonstrates an invasive cancer observed only at DBT and not at DM.

Table 4 summarizes the conspicuity analysis across views within each modality (CC DM vs MLO DM and CC DBT vs MLO DBT). For both DM and DBT, the OR for high conspicuity was higher at the CC than the MLO view (DM vs DBT OR, 1.6 [95% CI: 1.3, 1.9] vs 1.7 [95% CI: 1.3, 2.1], respectively; $P < .01$ for both). The higher OR at the CC view was also observed in the subgroup analysis of invasive carcinomas. In Tables 3 and 4, in all analyses of conspicuity and visibility, the standard error for the reader intercept random effect is large compared with the reader intercept variance, suggesting that these results may also likely apply to other readers. Figure 2

Table 4: Odds of High Conspicuity and Odds of Visibility versus View within Each Modality

	DM		DBT	
Parameter	Odds Ratio	*P* Value	Odds Ratio	*P* Value
Odds of high conspicuity				
All*				
MLO	…	…	…	…
CC	1.6 (1.3, 1.9) [0.18, 0.18]	<.01	1.7 (1.3, 2.1) [0.05, 0.06]	<.01
Invasive†				
MLO	…	…	…	…
CC	1.6 (1.3, 1.9) [0.23, 0.23]	<.01	1.6 (1.2, 2.2) [0.06, 0.08]	<.01
Odds of visibility				
All*				
MLO	…	…	…	…
CC	1.6 (1.2, 2.0) [0.07, 0.08]	<.01	3.6 (1.9, 7.0) [0.83, 0.96]	<.01
Invasive†				
MLO	…	…	…	…
CC	1.8 (1.3, 2.4) [0.11, 0.12]	<.01	2.3 (1.2, 4.2) [0.24, 0.33]	<.01

Note.—Data in parentheses are 95% confidence intervals; data in brackets are variance of random-effect reader intercepts and standard error of reader intercepts (logit scale). Odds of visibility were grades 2–5. CC = craniocaudal, DBT = digital breast tomosynthesis, DM = digital mammography, MLO = mediolateral oblique.

* There were 175 cancers in-field at both CC and MLO views (1050 interpretations).

† There were 122 invasive cancers in-field at both CC and MLO views (732 interpretations).

shows an invasive cancer observed only at the CC view, not at the MLO view. Figure 3 shows an invasive cancer better observed at the CC versus the MLO view. Figure 4 shows an invasive cancer better observed at the MLO versus CC view.

Table 5 demonstrates the raw proportions of high versus low conspicuity by modality, by modality within each view, and by view across modalities. Unlike the OR modeling, this cannot provide CIs or *P* values, but it can provide the percentages of the differences observed.

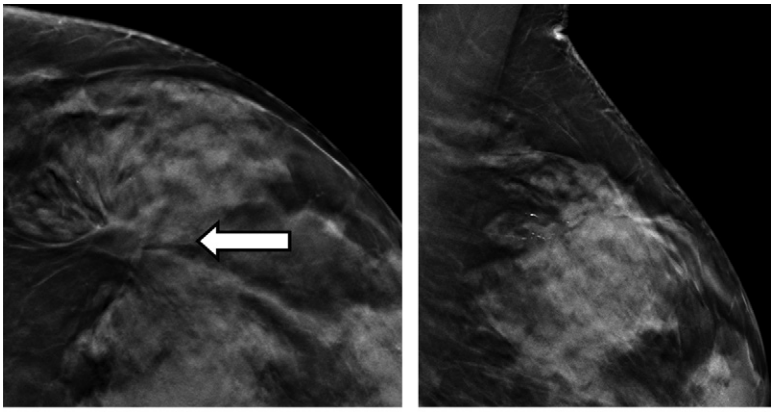
In the assessment of cancer visibility, some cancers were detected by using only a single modality (Table 3) or at only one view (Table 4). Cancers were more likely to be observed at DBT than at DM, both overall (OR, 5.4; 95% CI: 2.8, 10.5; $P < .01$) and in the subgroup analysis of invasive carcinomas (Tables 3, 6). As an assessment of cancer visibility within each modality, the OR was higher at the CC view than at the MLO view for both DM and DBT (Table 4).

In our study, 8.6% (36 of 420) of the time, invasive cancers were seen only at a reader's DBT reading, compared with 0.7% (three of 420) of the time for DM. When invasive cancers were analyzed according to view, all cancers were more likely to be seen at the CC view only for both DBT and DM. At DBT, 4.8% (25 of 525) of the time, cancers were only seen at the CC view and not at the MLO view. Similarly, at DM, 9.1% (48 of 525) of the time, cancers were only seen at the CC view and not at the MLO view. The interrater agreement is shown in Table 7.

Discussion

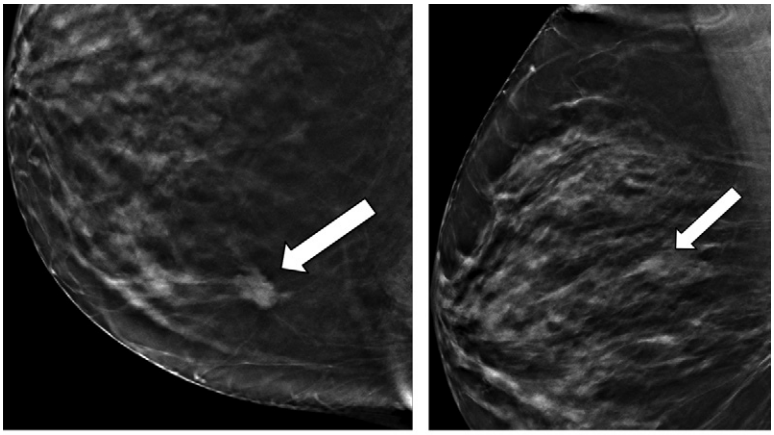
Previous studies (1–6) reported the benefit of digital breast tomosynthesis (DBT) compared with digital mammography (DM) for breast cancer screening. However, relatively little is known about differences in cancer conspicuity between the two modalities. The aim of our study was to investigate specific differences in breast cancer conspicuity by mammographic modality (DBT versus DM) and by mammographic view in all screening-detected breast cancers in over a 3-year period at our institution. Our data confirmed that cancers were more likely to have high conspicuity at DBT than at DM. When analyzed by view, the cancers were significantly more conspicuous at the CC DBT view than at the CC DM view, and at the MLO DBT view than at the MLO DM view, supporting that lesion conspicuity was improved at DBT versus DM, regardless of the view. Within the modality, the cancers were more conspicuous on the CC view than the MLO view ($P < .01$) for both DBT and DM. Some cancers were seen at only one modality or only one view. By modality, this occurred more frequently with DBT than DM. By view, this occurred more frequently at the CC view compared with the MLO view. Overall, our results found that cancers may have varying conspicuity on the basis of both modality and mammographic view. In general, DBT resulted in better conspicuity than DM, and the CC view more often resulted in better conspicuity than the MLO view.

We speculate that the improved conspicuity of breast cancers at DBT versus DM is from the multiple angular acquisition of DBT, which allows for reconstruction of a quasi-three-dimensional image stack. The ability to scroll through the multiple reconstructed sections of the DBT image stack allows for better lesion viewing by reducing the effect of overlapping normal fibroglandular tissue and better localization of lesions within the breast. However, it is not entirely clear why cancers are more conspicuous at the CC view than at the MLO view. We speculate that the improved conspicuity of cancers at the CC view is because of better compression



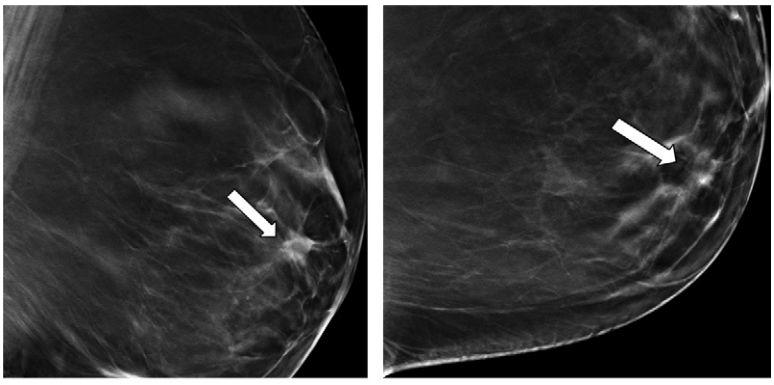
a. b.

Figure 2: Digital breast tomosynthesis in a 49-year-old woman with invasive ductal carcinoma seen only at the craniocaudal (CC) view. Subtle architectural distortion (arrow) is seen in the upper-outer quadrant on the **(a)** CC image and not definitely on the **(b)** mediolateral oblique image. The distortion was not seen at digital mammography (not shown).



a. b.

Figure 3: Digital breast tomosynthesis in a 78-year-old woman with invasive ductal carcinoma seen better at the craniocaudal (CC) view than the mediolateral oblique (MLO) view. A spiculated mass (arrow) is seen in the inner-central breast, more conspicuous on the **(a)** CC image compared with the **(b)** MLO image.



a. b.

Figure 4: Digital breast tomosynthesis in a 53-year-old woman with invasive ductal carcinoma seen better at the mediolateral oblique (MLO) view than the craniocaudal (CC) view. Although relatively uncommon, the images show a spiculated mass (arrow) in the upper-inner breast, which is more conspicuous on the **(a)** MLO image compared with the **(b)** CC image.

of the breast parenchyma at the CC view compared with the MLO view, at which force is often greatest on the pectoralis muscle rather than on the breast tissue. This would result in reduced tissue superimposition, increased lesion conspicuity, and perhaps a reduction in motion. In addition, the CC view (obtained at a 0° angle) is a more reproducible view when studies are compared year to year, perhaps making subtle changes more evident than at the more variable positioning at sequential MLO views. However, most abnormalities seen at one view will represent superimposition of normal structures. In a study by Sickles et al (18) of 61 273 consecutive screening digital mammograms, 2023 one-view abnormalities (3.3% of cases) were recalled for further investigation, and 82.7% were eventually found to represent superimposition of normal structures at further workup. Cancer was identified only in 36 of the 2023 (1.8%) one-view abnormalities, although the degree of suspicion at the one view of abnormality was not assessed in the study. Although uncommon because cancers may only be seen at one view, a suspicious one-view abnormality should not be attributed to tissue superimposition without further evaluation (18,19).

We also analyzed cancers that were only seen at one modality or one view. In 8.6% (36 of 420) of reader interpretations, invasive cancers were seen only at DBT, which is similar to previously reported publications (20–22) in which cancers were only seen at DBT (not at DM) 7%–73% of the time. Although others have previously explored this question, to our knowledge, none have specifically analyzed lesion conspicuity by view; rather, these studies focused on direct comparison of the two modalities (DBT vs DM) regardless of differences between mammographic views within each modality, as we have explored here. When analyzed by view, cancers were better seen or only seen more often at the CC view at both DBT and DM in our study. Our results suggest that cancer conspicuity is dependent not only on the modality but also on the view. Our results confirm and further expand upon those reported by Lång et al (23), who previously reported lesion viewing was superior at DBT compared with DM.

The use of one-view MLO DBT for screening has been explored, but our results show the CC view may be superior to the MLO view in depicting cancer conspicuity when the lesion is within the field of view; therefore, both views are important to optimize cancer detection because the MLO DBT is necessary to image the axillary tail and areas high on the chest wall that are less likely to be included at the CC view (24). In addition, because some malignant lesions were seen at only one view, both DBT views should be obtained to optimize screening outcomes.

Table 5: Cancers with High Conspicuity by Modality and by View within Modality

Comparison	Reader Interpretations
DBT versus DM*	
More conspicuous at DBT	177/591 (29.9)
Equally conspicuous at both modes	377/591 (63.8)
More conspicuous at DM	37/591 (6.3)
Invasive cancers only (DBT vs DM)†	
More conspicuous at DBT	138/420 (32.9)
Equally conspicuous at both modes	264/420 (62.9)
More conspicuous at DM	18/420 (4.3)
CC view (DBT vs DM)‡	
More conspicuous at DBT	178/552 (32.2)
Equally conspicuous at both modalities	333/552 (60.3)
More conspicuous at DM	41/552 (7.4)
MLO view (DBT vs DM)§	
More conspicuous at DBT	195/564 (34.6)
Equally conspicuous at both modes	301/564 (53.4)
More conspicuous at DM	68/564 (12.1)
DBT (CC view vs MLO view)‖	
More conspicuous at CC view	125/525 (23.8)
Equally conspicuous at both views	359/525 (68.4)
More conspicuous at MLO view	41/525 (7.8)
DM (CC view vs MLO view)‖	
More conspicuous at CC view	150/525 (28.6)
Equally conspicuous at both views	321/525 (61.1)
More conspicuous at MLO view	54/525 (10.3)

Note.—Data are numerator/denominator; data in parentheses are percentages. High conspicuity refers to grade 4 or 5. CC = craniocaudal, DBT = digital breast tomosynthesis, DM = digital mammography, MLO = mediolateral oblique.

* There were 591 interpretations (197 cancers by each of three readers).

† There were 420 interpretations (140 invasive cancers by each of three readers).

‡ There were 552 interpretations (184 cancers in-field in CC view by each of three readers).

§ There were 564 interpretations (188 cancers in-field in MLO view by each of three readers).

‖ There were 525 interpretations (175 cancers in-field at both views by each of three readers).

Table 6: Cancers Visible by Modality and by View within Modality

Comparison	Reader Interpretations
DBT versus DM*	
Seen at both	532/591 (90)
Seen at DBT only	48/591 (8.1)
Seen at DM only	5/591 (0.8)
Seen at neither	6/591 (1)
Invasive cancers only (DBT vs DM)†	
Seen at both	375/420 (89.3)
Seen at DBT only	36/420 (8.6)
Seen at DM only	3/420 (0.7)
Seen at neither	6/420 (1.4)
CC view (DBT vs DM)‡	
Seen at both	481/552 (87.1)
Seen at DBT only	61/552 (11.1)
Seen at DM only	4/552 (0.7)
Seen at neither	6/552 (1.1)
MLO view (DBT vs DM)§	
Seen at both	446/564 (79.1)
Seen at DBT only	79/564 (14)
Seen at DM only	19/564 (3.4)
Seen at neither	20/564 (3.5)
DBT (CC view vs MLO view)‖	
Seen at both	490/525 (93.3)
Seen at CC view only	25/525 (4.8)
Seen at MLO view only	1/525 (0.2)
Seen at neither	9/525 (1.7)
DM (CC view vs MLO view)‖	
Seen at both	415/525 (79)
Seen at CC view only	48/525 (9.1)
Seen at MLO view only	18/525 (3.4)
Seen at neither	44/525 (8.4)

Note.—Data are numerator/denominator; data in parentheses are percentages.Visibility was considered to be conspicuity grades 2–5. CC = craniocaudal, DBT = digital breast tomosynthesis, DM = digital mammography, MLO = mediolateral oblique.

* There were 591 interpretations (197 cancers by each of three readers).

† There were 420 interpretations (140 invasive cancers by each of three readers).

‡ There were 552 interpretations (184 cancers in-field at CC view by each of three readers).

§ There were 564 interpretations (188 cancers in-field at MLO view by each of three readers).

‖ There were 525 interpretations (175 cancers in-field at both views by each of three readers).

Our data indicate that there was reader variability for both DBT and DM overall and for the specific mammographic views for each modality; this finding is not unexpected because of the multitude of factors that influence performance of the radiologists. However, we found that interrater agreement tended to be higher with DBT than with DM, suggesting that DBT may have yet another advantage over DM in achieving a higher degree of consistency between radiologists.

Our study had several limitations. Our data were derived from a single DBT vendor and the DBT images were acquired with a narrow angle 15° tomosynthesis sweep. Therefore, our results may not be generalizable to other DBT manufacturers, particularly those that acquire images with a wider acquisition angle. Although relatively little is known regarding the differences in conspicuity between wide angle and narrow angle DBT systems, the study by Scaduto et al (25) is a limited study of six patients with nine masses showed that masses were more conspicuous with a wide angle (50°) tomosynthesis protocol compared with a narrower angle (15°). Conversely, in the study by Fajardo et al (26), in which three readers evaluated 61 DBT examinations with 78 findings, readers found no significant difference in conspicuity between narrow angle (15°) and wider angle (30°) DBT for conspicuity of masses and distortion, whereas calcifications were significantly more conspicuous at narrow angle DBT. In addition, the field of

Table 7: Interrater Agreement for High Conspicuity and Visibility within Each Modality

Parameter	Fleiss κ	*P* Value
DM		
Seen versus not seen	0.41 (0.33, 0.49)	<.01
High versus low conspicuity	0.40 (0.32, 0.48)	<.01
DBT		
Seen versus not seen	0.44 (0.36, 0.52)	<.01
High versus low conspicuity	0.42 (0.34, 0.50)	<.01

Note.—Data in parentheses are 95% confidence intervals. High conspicuity refers to grade 4 or 5; visibility refers to grade 2–5. All *P* values were versus null hypothesis of only chance agreement between raters. DBT = digital breast tomosynthesis, DM = digital mammography.

synthetic imaging is evolving and our results may not be generalizable to the higher spatial resolution DBT units that have been introduced since the completion of our data collection. As DBT technology has advanced, a few DBT vendors have incorporated synthetic, two-dimensional-like images that are reconstructed from the tomosynthesis data set, which obviates DM imaging. This rapid technology evolution introduced yet another limitation in our study. Because our study period concluded before synthesized imaging was incorporated into DBT screening, our results may not be translated to screening, which includes such synthesized two-dimensional images in the place of DM. Additionally, our population included only 197 screening-detected cancers, limiting the power of subgroup analyses. Our study environment also did not mimic the environment encountered in clinical practice. Because the aim of our study was to evaluate the conspicuity of known cancers, our readers were provided with the location of the cancers, which is different than a clinical screening practice. In addition, the lack of a washout period between DM and DBT interpretations may have potentially introduced reader bias.

Our results support the use of two-view digital breast tomosynthesis screening because we showed that some cancers are better seen or, on occasion, only seen at one of the two screening views. Radiologists should be aware that findings suspicious for cancer seen at only one view may be clinically significant and therefore should be completely evaluated. Future studies including a larger number of breast cancer cases and more readers are needed to corroborate our results.

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