Effect of Breast Augmentation on the Accuracy of Mammography and Cancer Characteristics

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Context Breast augmentation is not associated with an increased risk of breast cancer; however, implants may interfere with the detection of breast cancer thereby delaying cancer diagnosis in women with augmentation.

Objective To determine whether mammography accuracy and tumor characteristics are different for women with and without augmentation.

Design, Setting, and Participants A prospective cohort of 137 women with augmentation and 685 women without augmentation diagnosed with breast cancer between January 1, 1995, and October 15, 2002, matched (1:5) by age, race/ethnicity, previous mammography screening, and mammography registry, and 10533 women with augmentation and 974915 women without augmentation and without breast cancer among 7 mammography registries in Denver, Colo; Lebanon, NH; Albuquerque, NM; Chapel Hill, NC; San Francisco, Calif; Seattle, Wash; and Burlington, Vt.

Main Outcome Measures Comparison between women with and without augmentation of mammography performance measures and cancer characteristics, including invasive carcinoma or ductal carcinoma in situ, tumor stage, nodal status, size, grade, and estrogen-receptor status.

Results Among asymptomatic women, the sensitivity of screening mammography based on the final assessment was lower in women with breast augmentation vs women without (45.0% [95% confidence interval {CI}, 29.3%-61.5%] vs 66.8% [95% CI, 60.4%-72.8%]; $P=.008$), and specificity was slightly higher in women with augmentation (97.7% [95% CI, 97.4%-98.0%] vs 96.7% [95% CI, 96.6%-96.7%]; $P<.001$). Among symptomatic women, both sensitivity and specificity were lower for women with augmentation compared with women without but these differences were not significant. Tumors were of similar stage, size, estrogen-receptor status, and nodal status but tended to be lower grade ($P=.052$) for women with breast augmentation vs without.

Conclusions Breast augmentation decreases the sensitivity of screening mammography among asymptomatic women but does not increase the false-positive rate. Despite the lower accuracy of mammography in women with augmentation, the prognostic characteristics of tumors are not influenced by augmentation.

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Breast augmentation is the third most common type of plastic surgery performed for cosmetic reasons in the United States, with 268888 procedures in 2002.[1] In 2 studies conducted in the late 1980s, between 3.3 and 8.1 per 1000 women reported ever having breast implants.[2,3] Although breast implants have not been found to be associated with an increased risk of breast cancer,[4,5] implants may interfere with routine mammography evaluation; therefore, women with breast augmentation may be more likely to be diagnosed with advanced disease.[6-16] Previous studies of breast cancer following breast augmentation have typically had small study samples and yield conflicting results as to whether breast implants delay cancer diagnosis.[4,7,8,16-25] In addition, these studies include cancers diagnosed in the early 1980s when routine screening mammography was uncommon[26] and radiologists did not use implantation displacement views, a technique that improves visualization of breast tissue in women with implants.[12]

Two recent larger studies of breast cancer following augmentation mammoplasty suggest breast cancer diagnosis may be delayed in women with augmentation.[4,7] Brinton et al[4] found women with breast implants (N=78) tended to have later-stage disease compared with women without augmenta-

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tion (35% vs 17% with regional or distant disease); however, this difference was not statistically significant. Skinner et al[7] found that mammography was less sensitive for women with augmentation (N=99) compared with women without augmentation (66.3% vs 94.6%) and that women with augmentation were more likely to be diagnosed with palpable tumors (83% vs 59%), invasive carcinoma (82% vs 72%), and to have nodal involvement (48% vs 36%). Although both studies were relatively large compared with earlier studies, they also included breast cancers diagnosed in the early 1980s.

This study used recent prospective data from 7 US mammography registries that participate in the Breast Cancer Surveillance Consortium (BCSC)[27] to examine the effect of breast augmentation on mammography accuracy and cancer characteristics. Because the majority of women in the BCSC have undergone routine screening mammography during a time when displacement views are standard of care for women with augmentation, this large cohort can better answer the question of whether breast implants interfere with mammography and thereby delay cancer detection among women with augmentation.

METHODS

Data Sources

Women were selected from 7 mammography registries that form the National Cancer Institute–funded BCSC, which can be found at http://breastscreening.cancer.gov.[27] The 7 registries were Carolina Mammography Registry (CMR), Chapel Hill, NC; Colorado Mammography Project (CMAP), Denver; Group Health Cooperative (GHC), Seattle, Wash; New Hampshire Mammography Network (NHMN), Lebanon; New Mexico Mammography Project (NMMP), Albuquerque; San Francisco Mammography Registry (SFMR), San Francisco, Calif; and Vermont Breast Cancer Surveillance System (VBCSS), Burlington. These population-based mammography registries include screening and diagnostic mammography examinations performed in defined catchment areas. To determine cancer status and tumor characteristics, each mammography registry links to a state cancer registry (CMAP, CMR, NHMN, VBCSS) or regional Surveillance, Epidemiology, and End Results program (GHC, NMMP, SFMR). Some registries additionally link to pathology databases (CMR, GHC, NHMN, NMMP, VBCSS). Cancer ascertainment from these combined sources is estimated to be more than 94.3% complete.[28] Each registry has approval from its institutional review board to collect these data for analysis.

Study Sample

Women were included in analyses if they had a mammography examination between January 1, 1995, and October 15, 2002, and were consistent about reporting the presence or absence of breast augmentation. We excluded women with a personal history of breast cancer (self-report or prior diagnosis in the cancer registry or pathology database); self-report of prior mastectomy or breast reconstruction, or augmentation for only 1 breast (total of 5%); or women with an inconsistent reporting of breast augmentation once augmentation was first reported (eg, augmentation reported at 1 examination and no augmentation reported at a future examination, $<$1%). The most recent mammography examination in the study period was designated the index examination.

Because women with breast augmentation were younger, more likely to be white and non-Hispanic, and more likely to have had a mammogram before the index examination, which may influence the sensitivity of mammography, and we had a limited number of women with augmentation and breast cancer, we matched each woman with augmentation and breast cancer to 5 women without augmentation but with breast cancer by age (plus or minus 3 years), race/ethnicity (white non-Hispanic, black non-Hispanic, Hispanic, Asian, other), whether or not their index examination was within 2 years of diagnosis, whether the index examination was a first or subsequent mammogram, and mammography registry. Women with augmentation were also more likely to have dense breasts, have a family history of breast cancer, and be premenopausal or taking hormone therapy; however, we did not match by these variables as they were missing for 13% to 24% of women. Instead, we did a sensitivity analysis by adjusting for these variables to see if the results changed.

The sensitivity and specificity of mammography were based on a 1-year follow-up. For calculation of sensitivity and specificity, we excluded mammograms occurring after December 31, 2000, to allow sufficient time to detect cancers in the year following a mammogram. To calculate sensitivity, we also excluded mammograms occurring more than 1 year before cancer diagnosis.

Measures and Definitions

Demographic information and a self-reported breast health history were obtained at the time of each mammography examination that included birth date, race, ethnicity, current symptoms, breast augmentation status, history of mastectomy or breast reconstruction, family history of breast cancer, menopausal status, current postmenopausal hormone therapy use, and time since last mammography examination. Women were considered to have breast augmentation if augmentation was either self-reported on the questionnaire or indicated on the radiologist's report. Women who reported a breast lump or nipple discharge were considered to be symptomatic. Women were considered to have a family history of breast cancer if they reported having at least 1 female first-degree relative (mother, sister, or daughter) with breast cancer. Women aged 55 years or older were assumed to be perimenopausal/postmenopausal and those younger than 40 years were assumed to be premenopausal. Women aged 40 to 54 years were considered to be perimenopausal/postmenopausal if both ovaries had been removed, menstruation had stopped permanently, or they were taking hormone therapy.

Mammograms performed for routine screening in women with augmentation were often indicated to be diagnostic examinations by radiologists because implantation displacement views must be read in addition to standard compression views; therefore, the radiologists' indication for examination cannot reliably identify screening examinations in women with augmentation. To allow a similar definition of screening mammography for women with or without augmentation, we defined mammography examinations of asymptomatic women occurring more than 9 months after any prior mammogram as *screening* examinations.

Mammographic assessments were based on the American College of Radiology Breast Imaging Reporting and Data System (BI-RADS) coding scheme.[29] A mammogram was considered *positive* if it was given a final BI-RADS assessment code of 4 (suspicious abnormality), 5 (highly suggestive of malignancy), or 0 (need additional imaging evaluation) at the end of the screening work-up. A mammogram was considered *negative* if it was given a 1 (negative), 2 (benign finding), or 3 (probably benign finding) with a recommendation for short interval or routine follow-up. The BI-RADS assessments of 3 (probably benign finding) with a recommendation for immediate follow-up were recoded to a BI-RADS of 0. If a mammogram had an initial BI-RADS assessment of 0 and a nonzero assessment within 90 days, we used the first nonzero assessment as the *final assessment*.

Time since prior mammography was determined by using dates of prior mammography examinations recorded in each mammography registry and self-reported information. Mammograms were considered *first examinations* if the woman self-reported no history of prior mammography and there was no evidence of prior mammography in any mammography registry, or the time since prior mammography was 5 years or longer. Mammograms were considered to be *subsequent examinations* if time since prior mammography was less than 5 years.

Women were considered to have mammographically dense breasts when extremely dense or heterogeneously dense was reported according to BI-RADS density categories[29] or when classified as dense according to a 2-category system of dense and nondense. Women with nondense breasts were those that had BI-RADS categories of entirely fatty or scattered fibroglandular densities reported or were indicated to have nondense breasts when a 2-category system was used.

Breast cancer was defined as either invasive carcinoma or ductal carcinoma in situ according to a cancer registry or pathology database. All breast cancers were classified according to the American Joint Committee on Cancer Staging system.[30] Invasive cancers were categorized by nodal status, tumor size, grade, and estrogen-receptor status. Tumor characteristics were slightly less likely to be missing for women with augmentation but in general the amount of missing data was similar among women with or without augmentation: 8% and 10% for stage, 2% and 4% for nodal status, 8% and 12% for tumor size, 16% and 18% for tumor grade, and 32% and 35% for estrogen-receptor status.

Data Analysis

Sensitivity and Specificity. A 1-year follow-up period is the standard for calculating the accuracy of mammography.[29,31] We define the *sensitivity* of mammography as the proportion of positive mammograms among women diagnosed with breast cancer within 1-year of their examination. *Specificity* was defined as the proportion of negative mammograms among women without cancer. Sensitivity and specificity were calculated separately for screening mammograms and mammograms among symptomatic women.

Exact binomial 95% confidence intervals (CIs) were calculated for estimated sensitivity and specificity and χ^2 tests were used to compare these estimates for women with and without augmentation. Logistic regression was used to adjust sensitivity and specificity for age, breast density, whether the index examination was a first or subsequent mammogram, and mammography registry. Because specificity was calculated from the entire cohort of women without cancer, the larger sample size allowed specificity to be additionally adjusted for race/ethnicity, family history, menopausal status, and hormone therapy use.

Tumor Characteristics. For women diagnosed with breast cancer, the distributions of cancer characteristics were estimated and compared for women with and without augmentation by using χ^2 tests for categorical outcomes (stage, nodal status, grade, estrogen-receptor status) and the Wilcoxon rank sum test for tumor size. We fit logistic regression models adjusting for age, first vs subsequent mammography, and mammography registry to compare cancer characteristics among women with and without breast augmentation. We did not adjust for race/ethnicity because the numbers of nonwhite women were too small to allow stable parameter estimation.

Analyses were performed by using SAS version 8.02 (SAS Institute, Cary, NC) and $P<.05$ was considered statistically significant.

RESULTS

There were 141 women with augmentation and 20 738 women without augmentation diagnosed with breast cancer between January 1, 1995, and October 15, 2002, and 10 849 women with augmentation and 1 016 684 women without augmentation and without breast cancer. The prevalence of augmentation in this screening population of women without a history of breast cancer was 11 per 1000 women. Women with augmentation were younger with denser breasts, more likely to be white and non-Hispanic, more likely to have had a prior mammogram, and more likely to use hormone therapy if menopausal (TABLE 1).

Four women with augmentation and breast cancer could not be matched to 5 women without augmentation because 2 were of unknown race, 1 was of mixed race, and for 1 woman it was not known whether she had a prior mammogram. The remaining 137 women with augmentation were matched to 685 women without augmentation for comparison. Among women with a mammogram within 1 year of cancer diagnosis, women with augmentation were more likely to present with symptoms: 47% of women with augmentation and 35% of women without reported the presence of a lump or nipple discharge ($P=.03$).

To calculate the sensitivity of mammography, we selected mammograms occurring within 1 year before cancer diagnosis and before December 31, 2000 (86 augmented, 434 nonaugmented). To estimate the sensitivity of screening mammography (as defined in the "Methods" section), we excluded mammograms of women with self-reported symptoms (41 with augmentation and 145 without augmentation). In addition, we excluded mammograms of women with missing symptom information and mammograms occurring less than 10 months after a previous mammogram, resulting in screening mammograms of 40 women with augmentation and 238 women without for analysis. The distribution of BI-RADS assessments differed for women with and without augmentation, with a lower proportion of women with augmentation having a BI-RADS assessment of 0 (7.5% vs 17.2%) and 5 (0% vs 11.8%), a similar proportion with an assessment of 4 (37.5% vs 37.8%), and a higher proportion with a 1, 2, or 3 (55.0% vs 33.2%). The raw sensitivity of screening mammography was lower for women with augmentation vs without (45.0% vs 66.8%; $P=.008$; TABLE 2). Sensitivity remained significantly lower after adjust-

Table 1. Demographic Characteristics of Study Population*

	No. of Women (%)			
	With Breast Cancer		Without Breast Cancer	
Characteristics	With Augmentation (n = 141)	Without Augmentation (n = 20 738)	With Augmentation (n = 10 849)	Without Augmentation (n = 1 016 684)
Age, y				
<40	7 (5.0)	853 (4.1)	1436 (13.2)	106 320 (10.5)
40-49	52 (36.9)	4102 (19.8)	4934 (45.5)	333 861 (32.8)
50-59	57 (40.4)	5446 (26.3)	3347 (30.9)	258 480 (25.4)
60-69	19 (13.5)	4755 (22.9)	886 (8.2)	161 995 (15.9)
≥70	6 (4.3)	5582 (26.9)	246 (2.3)	156 028 (15.3)
Race†				
Non-Hispanic white	130 (93.5)	16 725 (82.1)	8755 (92.3)	683 555 (77.0)
Non-Hispanic black	2 (1.4)	1472 (7.2)	101 (1.1)	69 008 (7.8)
Hispanic	5 (3.6)	1262 (6.2)	293 (3.1)	75 834 (8.5)
Asian	1 (0.7)	675 (3.3)	234 (2.5)	37 849 (4.3)
Other	1 (0.7)	233 (1.1)	106 (1.1)	21 514 (2.4)
Time from diagnosis to prior mammogram, y				
≤2	124 (87.9)	17 890 (86.3)	NA	NA
>2	17 (12.1)	2848 (13.7)	NA	NA
No. of mammograms†				
1	12 (8.6)	3196 (16.1)	2233 (20.9)	181 996 (18.5)
>1	128 (91.4)	16 644 (83.9)	8444 (79.1)	804 036 (81.5)
Mammographic breast density†				
Not dense	37 (39.4)	7482 (47.5)	3671 (45.2)	432 272 (53.3)
Dense	57 (60.6)	8262 (52.5)	4450 (54.8)	379 091 (46.7)
Family history of breast cancer†				
No	101 (83.5)	14 626 (81.0)	7907 (87.4)	780 313 (87.2)
Yes	20 (16.5)	3432 (19.0)	1136 (12.6)	114 257 (12.8)
Menopausal and hormone therapy status†				
Premenopausal	42 (39.3)	5770 (34.3)	4238 (46.7)	324 012 (37.7)
Menopausal and no hormone therapy	19 (17.8)	5903 (35.1)	1544 (17.0)	296 422 (34.5)
Menopausal and hormone therapy	46 (43.0)	5142 (30.6)	3287 (36.2)	238 378 (27.8)

Abbreviation: NA, not applicable.
*Because of rounding, percentages may not all total 100.
†Information was missing for women with and without augmentation for race (n = 2 and n = 371 for women with cancer, and n = 1360 and n = 128 924 for women without cancer), number of mammograms (n = 1 and n = 898 with cancer, and n = 172 and n = 30 652 without cancer), mammographic breast density (n = 47 and n = 4994 with cancer, and n = 2728 and n = 205 321 without cancer), family history of breast cancer (n = 20 and n = 2680 with cancer, and n = 1806 and n = 122 114 without cancer), and menopausal and hormone therapy status (n = 34 and n = 3923 with cancer, and n = 1780 and n = 157 872 without cancer).

ment for age, breast density, first vs subsequent mammogram, and mammography registry ($P=.02$).

We also estimated the sensitivity of mammography among symptomatic women by using data from 41 women with augmentation and 145 women without augmentation with self-reported symptoms. The sensitivity of mammography was 8 percentage points lower in women with augmenation (73.2% for women with augmentation and 81.4% for women without augmentation, Table 2); however, this difference was not statistically significant ($P=.25$). This difference remained nonsignificant after adjustment for age, breast density, first vs subsequent mammogram, and mammography registry ($P=.69$).

To estimate the specificity of screening mammography, we excluded mammograms of women with self-reported symptoms (1006 women with augmentation and 62625 women without augmentation). In addition, we excluded mammograms of women with missing symptom information and mammograms occurring less than 10 months after a previous mammogram,

Table 2. Sensitivity and Specificity of Mammography by Augmentation and Symptom Status

	Asymptomatic Women			Symptomatic Women		
	With Augmentation	Without Augmentation	*P* Value	With Augmentation	Without Augmentation	*P* Value
With cancer*						
Sample size, No. (%)	40 (29.2)	238 (34.7)		41 (29.9)	145 (21.2)	
Raw sensitivity (95% CI)	45.0 (29.3-61.5)	66.8 (60.4-72.8)	.008†	73.2 (57.1-85.8)	81.4 (74.1-87.4)	.25†
Adjusted sensitivity (95% CI)‡	46.5 (31.6-62.2)	67.2 (60.3-72.5)	.02§	74.0 (56.0-85.4)	77.4 (68.0-83.4)	.69§
Without cancer						
Sample size, No. (%)	9067 (83.6)	854 997 (84.1)		1006 (9.3)	62 625 (6.2)	
Raw specificity (95% CI)	97.7 (97.4-98.0)	96.7 (96.6-96.7)	<.001†	86.4 (84.1-88.4)	87.2 (87.0-87.5)	.43†
Adjusted specificity (95% CI)∥	98.2 (97.8-98.5)	97.3 (97.2-97.3)	<.001§	85.7 (82.5-88.5)	88.4 (88.1-88.7)	.06§

Abbreviation: CI, confidence interval.
*Among women with a mammogram within 1 year of cancer diagnosis.
†Based on χ^2 test.
‡Adjusted for age, breast density, first vs subsequent mammogram, and registry using logistic regression.
§Based on Wald test from logistic regression model.
∥Adjusted for age, breast density, first vs subsequent mammogram, race/ethnicity, menopausal status, current hormone therapy use, and registry using logistic regression.

Table 3. Distribution of Tumor Characteristics by Augmentation and Symptom Status Among Women With a Mammogram Within 1 Year of Cancer Diagnosis

	No. of Women (%)					
	Asymptomatic			Symptomatic		
Characteristic	With Augmentation (n = 40)	Without Augmentation (n = 238)	*P* Value*	With Augmentation (n = 41)	Without Augmentation (n = 145)	*P* Value*
Type						
DCIS	10 (25.0)	52 (21.8)	.66	0	14 (9.7)	.04
Invasive	30 (75.0)	186 (78.2)		41 (100)	131 (90.3)	
AJCC stage						
0 or I	27 (71.0)	144 (69.6)	.85	17 (50.0)	73 (54.9)	.61
II, III, or IV	11 (29.0)	63 (30.4)		17 (50.0)	60 (45.1)	
Nodal involvement†						
No	22 (75.9)	133 (73.9)	.82	29 (70.7)	86 (68.2)	.77
Yes	7 (24.1)	47 (26.1)		12 (29.3)	40 (31.8)	
Grade†						
I or II	19 (76.0)	102 (68.5)	.45	29 (82.9)	53 (55.2)	.004
III or IV	6 (24.0)	47 (31.5)		6 (17.1)	43 (44.8)	
Estrogen-receptor status†						
Positive	18 (85.7)	95 (81.9)	.67	21 (95.5)	58 (76.3)	.05
Negative	3 (14.3)	21 (18.1)		1 (4.6)	18 (23.7)	
Tumor size, mm†						
No. of women	27	157		35	114	
Median (interquartile range)	15.0 (10.0-20.0)	12.0 (8.0-20.0)	.25‡	13.0 (10.0-20.0)	17.0 (12.0-27.0)	.02‡

Abbreviations: AJCC, American Joint Committee on Cancer; DCIS, ductal carcinoma in situ.
*Based on χ^2 test unless otherwise noted.
†Invasive only.
‡Based on Wilcoxon rank sum test.

resulting in screening mammograms of 9067 women with augmentation and 854 997 women without augmentation for analysis. Those women with augmentation were more likely to have a BI-RADS assessment of 1, 2, or 3 (97.7% vs 96.7%) and less likely to have an assessment of 0 (1.8% vs 2.4%) or 4 (0.4% vs 0.9%) compared with women without augmentation. There were very few assessments of 5 in both groups (1 woman with augmentation and 234 women without augmentation). The specificity of screening mammography was 1 percentage point higher for women with augmentation vs women without augmentation (Table 2, $P<.001$). This difference remained after adjusting for age, race/ethnicity, first vs subsequent mammogram, breast density, family history, menopausal status, current hormone therapy use, and mammography registry ($P<.001$). Among symptomatic women without breast cancer (1006 women with augmentation and 62 625 women without), adjusted specificity tended to be lower for women with augmentation compared with women without (Table 2, $P=.06$).

TABLE 3 shows the corresponding distributions of tumor characteristics for the women with a mammogram before January 1, 2001, and cancer diagnosis within 1 year of the mammogram. Among asymptomatic women, there were no significant differences in tumor characteristics in women with augmentation compared with women without despite the difference in sensitivity; however, the median tumor size at detection for women with augmentation was 3 mm larger. In contrast, among symptomatic women, women with augmentation were more likely to be diagnosed with invasive cancer ($P=.04$), but those cancers were smaller ($P=.02$), lower grade ($P=.004$), and more likely to be estrogen-receptor positive ($P=.05$).

TABLE 4 displays the distributions of tumor characteristics for the entire matched sample. There were no significant differences in the percentages of invasive cancer or distributions of tumor stage, nodal status, tumor size, or estrogen-receptor status for women with augmentation compared with women without augmentation ($P>.10$ in all cases); however, women with augmentation tended to have lower grade tumors ($P=.052$). Among women with augmentation, 52.0% had grade II cancer and only 25.5% had grade III or IV compared with 40.1% grade II cancer and 37.3% grade III or IV among women without augmentation.

Results from the logistic regression models (TABLE 5) that adjusted for age, previous screening, and mammography registry were similar to unadjusted results. There were no significant differences in the odds of invasive cancer, stage II or higher cancer, nodal involvement, tumors of more than 20 mm, or estrogen-receptor–negative status among women with augmentation compared with women without augmentation; however, women with augmentation were less likely to have grade III or IV cancer (odds ratio [OR], 0.52; 95% CI, 0.31-0.85; $P=.02$). Results were similar after additionally adjusting for menopausal status, current hormone therapy use, family history, or breast density; however, the difference in grade became nonsignificant after adjusting for menopausal/hormone therapy status (OR, 0.60; 95% CI, 0.32-1.09) or breast density (OR, 0.65; 95% CI, 0.34-1.18).

COMMENT

Breast augmentation may interfere with the interpretation of mammography examinations because implants are radio-opaque.[6-15] To improve the accuracy of mammography in women with breast augmentation, Eklund et al[10] proposed the use of breast implant displacement views, which are performed while the breast tissue is pulled forward and the breast implant is pushed back to improve visualization

Table 4. Distribution of Tumor Characteristics by Augmentation Status

Characteristic	No. of Women (%): With Augmentation (n = 137)	No. of Women (%): Without Augmentation (n = 685)	*P* Value*
Type			
DCIS	21 (15.3)	122 (17.8)	.48
Invasive	116 (84.7)	563 (82.2)	
AJCC stage			
0	21 (15.3)	122 (17.8)	.11
I	53 (38.7)	280 (40.9)	
II	49 (35.8)	177 (25.8)	
III or IV	3 (2.2)	36 (5.3)	
Unstaged	11 (8.0)	70 (10.2)	
Nodal status†			
Negative	78 (68.4)	388 (71.9)	.46
Positive	36 (31.6)	152 (28.1)	
Grade†			
I	22 (22.4)	104 (22.6)	.052
II	51 (52.0)	185 (40.1)	
III or IV	25 (25.5)	172 (37.3)	
Estrogen-receptor status†			
Positive	66 (83.5)	293 (80.1)	.48
Negative	13 (16.5)	73 (19.9)	
Tumor size, mm†			
No. of Women	107	491	
Mean (SD)	17.6 (14.1)	19.1 (16.4)	.64‡
Median (interquartile range)	15.0 (10.0-21.0)	15.0 (10.0-23.0)	

Abbreviations: AJCC, American Joint Committee on Cancer; DCIS, ductal carcinoma in situ.
*Based on χ^2 test unless otherwise noted.
†Invasive only. Information was missing for women with and without augmentation for nodal status (n = 2 and n = 23), grade (n = 18 and n = 102), estrogen-receptor status (n = 27 and n = 197), and tumor size (n = 8 and n = 43).
‡Based on Wilcoxon rank sum test.

of breast tissue. During a time when displacement views are the standard of care, we found that screening mammography missed 55% of the cancers in asymptomatic women with augmentation compared with 33% in similarly aged women without augmentation.

We report relatively low sensitivity and high specificity of screening mammography even among women without augmentation. This is because of 2 factors. First, we defined a positive mammogram by using the final assessment, which was based on a complete work-up (the results of all imaging performed following the screening mammogram).[31] Using the final assessment lowers sensitivity and increases specificity, because some mammograms that were initially given a positive BI-RADS assessment of 0 are resolved to a negative assessment after receiving additional imaging. Second, our study sample is relatively young because women with augmentation tend to be younger than a general screening population and these women were age-matched with women without augmentation. The sensitivity of mammography is lower in younger women because they tend to have dense breast tissue that can obscure signs of cancer[32-34] and may have more rapidly growing tumors.

Despite the lower sensitivity of mammography in women with augmentation, these women were diagnosed with cancer of similar stage, size, nodal status, and estrogen-receptor status and lower grade compared with women without augmentation. As found in other studies[19,23,25] among symptomatic women, women with augmentation had tumors with better prognostic characteristics, including smaller size, lower grade, and estrogen-receptor positive status. This suggests it may be easier to palpate breast masses in women with breast implants given their lower native breast volume[7] or because breast implants provide a firm platform to palpate against.[12,19,35] In addition, women with augmentation may be more breast aware or body conscious and hence seek medical care more quickly for breast changes or symptoms.

Several previous studies found similar or more favorable breast cancer characteristics in women with augmentation compared with women without augmentation[8,18-24]; however, the majority of women in these studies were not undergoing regular screening mammography and most presented with palpable lumps. Therefore, previous results cannot be generalized to a screening population. Two somewhat larger studies[4,7] found evidence supporting delayed diagnosis in women with augmentation. Brinton et al[4] compared breast cancer stage in 78 women with augmentation with 36 women without augmentation who had undergone other types of plastic surgery and found women with breast implants tended to have later stage disease (35% vs 17% with regional or distant disease), although this difference was not statistically significant. The study conducted by Skinner et al[7] compared 99 women with cancer in augmented breasts to 2857 cases in women without augmentation. They found that women with augmentation were more likely to be diagnosed with palpable tumors (83% vs 59%), invasive carcinoma (82% vs 72%), and have nodal involvement (48% vs 36%). Although women with augmentation in our study also presented more often with symptoms (47% vs 35%), the difference was smaller and the overall symptomatic cancer rate was lower. In addition, we found very small and nonsignificant differences between the groups for invasive disease (85% vs 82%), nodal involvement (32% vs 28%), and cancer stage (38% vs 31% with the American Joint Committee on Cancer stage II or higher). Taken together, these results suggest that women with and without augmentation are diagnosed with tumors of similar prognosis. The findings in this study may differ from earlier reports because of the fact that Brinton et al[4] and Skinner et al[7] included women diagnosed with cancer

Table 5. Cancer Characteristics for Women With and Without Augmentation, Adjusted for Age, First vs Subsequent Mammography, and Registry

Characteristic	No. of Women: With Augmentation (n = 137)	No. of Women: Without Augmentation (n = 685)	Odds Ratio (95% Confidence Interval)
Type			
DCIS	21	122	1.00
Invasive	116	563	1.20 (0.73-2.05)
AJCC stage			
0 or I	99	496	1.00
II, III, or IV	27	119	1.12 (0.68-1.80)
AJCC stage*			
I	78	374	1.00
II, III, or IV	27	119	1.05 (0.63-1.71)
Nodal involvement*†			
No	78	388	1.00
Yes	36	152	1.17 (0.74-1.80)
Grade*†			
I or II	73	289	1.00
III or IV	25	172	0.52 (0.31-0.85)
Estrogen-receptor status*†			
Positive	66	293	1.00
Negative	13	73	0.77 (0.38-1.45)
Tumor size, mm*†			
≤20	80	352	1.00
>20	27	143	0.81 (0.49-1.31)

Abbreviations: AJCC, American Joint Committee on Cancer; DCIS, ductal carcinoma in situ.
*Invasive only.
†Information was missing for women with and without augmentation for nodal status (n = 2 and n = 23), grade (n = 18 and n = 102), estrogen-receptor status (n = 27 and n = 197), and tumor size (n = 8 and n = 43).

in the 1980s, before the introduction of displacement views and when screening mammography was less widely practiced.[26]

We found asymptomatic women with augmentation have 5 fewer false-positive examinations per 1000 women screened than women without augmentation (34 vs 39 per 1000 women). Some women with breast implants develop thin layers of calcium in the peri-implant capsular tissue but these calcifications do not appear to mimic cancer or increase the chances of having a false-positive mammogram.[36] It should be reassuring to women with augmentation that their breast implants will not increase their probability of being called back for additional imaging or breast biopsy.

Our study has several limitations. First, we do not have information on implant type and placement[6,7,11] and capsular contracture,[6] which could influence mammography accuracy in women with augmentation. Silverstein et al[11] found that 39% to 49% of breast tissue is concealed in women with subglandular implants compared with only 9% to 28% of tissue in women with subpectoral placement. In contrast, Skinner et al[7] found no difference in mammography sensitivity for women by breast implant placement (sensitivity of 65.7% for submammary compared with 66.7% for subpectoral placement). Second, we rely on self-reported information of breast augmentation status combined with an indication of augmentation from the radiologist. A previous study[37] found self-report of augmentation to be very accurate; therefore, our combined measure should be reliable. Lastly, we were missing 13% to 24% of data for some possible confounding variables, such as breast density and hormone therapy status, and up to 35% of data for tumor characteristics. Breast density, family history, and hormone therapy status are most often missing because some participating facilities do not collect this information, and 1 state cancer registry did not collect estrogen-receptor status before 1998, contributing to the high missing rate for that outcome. We are not aware of any reporting bias related to breast augmentation status, hormone therapy use, breast density, or family history. Because we are using likelihood-based estimation, our estimates are unbiased if data are missing at random (ie, if missing data depend only on covariates included in the models). Despite these limitations, our study has the major advantage of using recent data from the BCSC, which include a large population of women undergoing screening mammography from multiple sites throughout the United States.

Although the sensitivity of screening mammography is lower in asymptomatic women with breast augmentation, there is no evidence that this results in more advanced disease at diagnosis compared with women without augmentation. Women with breast augmentation should be encouraged to have routine screening mammography at recommended intervals.

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REFERENCES

1. American Society of Plastic Surgeons. 2002 Quick facts on cosmetic and reconstructive plastic surgery. Available at: http://www.plasticsurgery.org/public_education/loader.cfm?url=/commonspot/security/getfile.cfm&PageID=6056. Accessibility verified December 18, 2003.
2. Bright RA, Jeng LL, Moore RM. National survey of self-reported breast implants: 1988 estimates. *J Long Term Eff Med Implants.* 1993;3:81-89.
3. Cook RR, Delongchamp RR, Woodbury M, Perkins LL, Harrison MC. The prevalence of women with breast implants in the United States—1989. *J Clin Epidemiol.* 1995;48:519-525.
4. Brinton LA, Lubin JH, Burich MC, Colton T, Brown SL, Hoover RN. Breast cancer following augmentation mammoplasty (United States). *Cancer Causes Control.* 2000;11:819-827.
5. Hoshaw SJ, Klein PJ, Clark BD, Cook RR, Perkins LL. Breast implants and cancer: causation, delayed detection, and survival. *Plast Reconstr Surg.* 2001;107:1393-1407.
6. Handel N, Silverstein MJ, Gamagami P, Jensen JA, Collins A. Factors affecting mammographic visualization of the breast after augmentation mammaplasty. *JAMA.* 1992;268:1913-1917.
7. Skinner KA, Silberman H, Dougherty W, et al. Breast cancer after augmentation mammoplasty. *Ann Surg Oncol.* 2001;8:138-144.
8. Carlson GW, Curley SA, Martin JE, Fornage BD, Ames FC. The detection of breast cancer after augmentation mammaplasty. *Plast Reconstr Surg.* 1993;91:837-840.
9. Fajardo LL, Harvey JA, McAleese KA, Roberts CC, Granstrom P. Breast cancer diagnosis in women with subglandular silicone gel-filled augmentation implants. *Radiology.* 1995;194:859-862.
10. Eklund GW, Busby RC, Miller SH, Job JS. Improved imaging of the augmented breast. *AJR Am J Roentgenol.* 1988;151:469-473.
11. Silverstein MJ, Handel N, Gamagami P, Waisman E, Gierson ED. Mammographic measurements before and after augmentation mammaplasty. *Plast Reconstr Surg.* 1990;86:1126-1130.
12. Eklund GW, Cardenosa G. The art of mammographic positioning. *Radiol Clin North Am.* 1992;30:21-53.

13. Gumucio CA, Pin P, Young VL, Destouet J, Monsees B, Eichling J. The effect of breast implants on the radiographic detection of microcalcification and soft-tissue masses. *Plast Reconstr Surg.* 1989;84:772-778.
14. Hayes H, Vandergrift J, Diner WC. Mammography and breast implants. *Plast Reconstr Surg.* 1988;82:1-8.
15. Douglas KP, Bluth EI, Sauter ER, et al. Roentgenographic evaluation of the augmented breast. *South Med J.* 1991;84:49-54.
16. Silverstein MJ, Handel N, Gamagami P, et al. Breast cancer diagnosis and prognosis in women following augmentation with silicone gel-filled prostheses. *Eur J Cancer.* 1992;28:635-640.
17. Schirber S, Thomas WO, Finley JM, Green AE, Ferrara JJ. Breast cancer after mammary augmentation. *South Med J.* 1993;86:263-268.
18. Leibman AJ, Kruse B. Breast cancer: mammographic and sonographic findings after augmentation mammoplasty. *Radiology.* 1990;174:195-198.
19. Clark CP, Peters GN, O'Brien KM. Cancer in the augmented breast: diagnosis and prognosis. *Cancer.* 1993;72:2170-2174.
20. Cahan AC, Ashikari R, Pressman P, Cody H, Hoffman S, Sherman JE. Breast cancer after breast augmentation with silicone implants. *Ann Surg Oncol.* 1995;2:121-125.
21. Holmich LR, Mellemkjaer L, Gunnarsdottir KA, et al. Stage of breast cancer at diagnosis among women with cosmetic breast implants. *Br J Cancer.* 2003;88:832-838.
22. Brinton LA, Malone KE, Coates RJ, et al. Breast enlargement and reduction: results from a breast cancer case-control study. *Plast Reconstr Surg.* 1996;97:269-275.
23. Birdsell DC, Jenkins H, Berkel H. Breast cancer diagnosis and survival in women with and without breast implants. *Plast Reconstr Surg.* 1993;92:795-800.
24. Deapen D, Hamilton A, Bernstein L, Brody GS. Breast cancer stage at diagnosis and survival among patients with prior breast implants. *Plast Reconstr Surg.* 2000;105:535-540.
25. Deapen DM, Bernstein L, Brody GS. Are breast implants anticarcinogenic? a 14-year follow-up of the Los Angeles Study. *Plast Reconstr Surg.* 1997;99:1346-1353.
26. Swan J, Breen N, Coates RJ, Rimer BK, Lee NC. Progress in cancer screening practices in the United States: results from the 2000 National Health Interview Survey. *Cancer.* 2003;97:1528-1540.
27. Ballard-Barbash R, Taplin SH, Yankaskas BC, et al. Breast Cancer Surveillance Consortium: a national mammography screening and outcomes database. *AJR Am J Roentgenol.* 1997;169:1001-1008.
28. Ernster VL, Ballard-Barbash R, Barlow WE, et al. Detection of ductal carcinoma in situ in women undergoing screening mammography. *J Natl Cancer Inst.* 2002;94:1546-1554.
29. D'Orsi CJ, Bassett LW, Feig SA, et al. Breast imaging reporting and data system. In: Bassett LW, Feig SA, Jackson VP, et al, eds. *American College of Radiology ACR Breast Imaging Reporting and Data System BI-RADS.* 3rd ed. Reston, Va: American College of Radiology; 1998.
30. AJCC cancer staging manual. In: Fleming ID, Cooper JS, Henson DE, et al, eds. *AJCC Cancer Staging Manual.* 5th ed. New York, NY: Lippincott-Raven; 1997:171-180.
31. Rosenberg RD, Yankaskas BC, Hunt WC, et al. Effect of variations in operational definitions on performance estimates for screening mammography. *Acad Radiol.* 2000;7:1058-1068.
32. Carney PA, Miglioretti DL, Yankaskas BC, et al. Individual and combined effects of age, breast density, and hormone replacement therapy use on the accuracy of screening mammography. *Ann Intern Med.* 2003;138:168-175.
33. Kerlikowske K, Carney PA, Geller B, et al. Performance of screening mammography among women with and without a first-degree relative with breast cancer. *Ann Intern Med.* 2000;133:855-863.
34. Kerlikowske K, Grady D, Barclay J, Sickles EA, Ernster V. Effect of age, breast density, and family history on the sensitivity of first screening mammography. *JAMA.* 1996;276:33-38.
35. Mogelvang LC. Oncologic aspects of augmentation mammaplasty. *Plast Reconstr Surg.* 1995;95:935-936.
36. Muzaffar AR, Rohrich RJ. The silicone gel-filled breast implant controversy: an update. *Plast Reconstr Surg.* 2002;109:742-748.
37. Garbers S, Terry MB, Toniolo P. Accuracy of self-report of breast implants. *Plast Reconstr Surg.* 1998;101:695-698.

History is the torch that is meant to illuminate the past, to guard us against the repetition of our mistakes of other days. We cannot join in the rewriting of history to make it conform to our comfort and convenience.
—Claude G. Bowers (1878-1958)

