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Performance of digital screening mammography among older women in the U.S

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Abstract

Background—Although healthy women aged 65 have a life expectancy of 20 years, there is a paucity of data on the performance of digital screening mammography among these women. We examined the performance and outcomes of digital screening mammography among a national group of women aged 65 and older.

Methods—Using Breast Cancer Surveillance Consortium data from 2005–2011 we included 296,496 full field digital screening mammograms among 133,042 women ages 65 and older without a history of breast cancer. We calculated sensitivity, specificity, positive predictive value (PPV), recall and 95% confidence intervals (95%CI) across the spectrum of age and breast density. We used multivariate logistic regression to compare mammography accuracy, cancer detection rates (CDRs), and tumor characteristics by age and breast density.

Results—Multivariate analyses showed a significant decrease in recall rate with age (p-value for trend<0.001) and significant increases in specificity, PPV_1, and CDR with age (p-value for trend <0.001, <0.001, and 0.01 respectively). Sensitivity did not vary significantly with age. Among women with cancer, the proportion with invasive disease increased with age from 76% at 65–74 years to 81% at 80+. There was a higher proportion of late stage cancers and positive lymph nodes in women ages 65–74 compared to older age groups.

Conclusions—Specificity, PPV_1, recall rate, and CDR of digital screening mammography improved with increased age. In addition, as age increased the proportion of invasive versus ductal carcinoma in-situ cases rose, while the proportion of cases with positive nodes decreased.

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Conflicts of Interest

None

INTRODUCTION

Breast cancer is responsible for most new cases of cancer among women with an estimated 29% of new cancer cases and 14% of cancer deaths among women estimated to be from breast cancer in 2014.[1] Approximately 41% of all incident breast cancers and 57% of all breast cancer deaths are among women ages 65 and older.[2] Although healthy women age 65 years have a 20 year life expectancy and those age 70 have life expectancy of 15.5 years [3], data are lacking on the benefits and harms of mammography screening in these women.

Current breast cancer screening recommendations from the American Cancer Society (ACS) are for annual screening mammography for women with an average risk of developing breast cancer beginning at age 40 along with an annual clinical breast exam (CBE) close to the time of and before an annual mammogram.[4] The United States Preventive Services Task Force (USPSTF) recommends screening mammography every 1 to 2 years, from age 50 to 74.[5] The National Cancer Institute is re-evaluating its past recommendations in light of the USPSTF recommendations and supporting more research.[6] Both the ACS and the USPSTF state that screening in older women should be considered on an individual basis through the evaluation of potential benefits and risks posed by the mammogram in relation to their current health condition and predicted life expectancy. In other words, if the woman is in good health and a candidate for treatment if cancer is detected, it may be appropriate to screen.

The only prior study to examine screening mammography performance in older U.S. women found screening mammography to be more accurate in older women compared to younger counterparts.[7] However, the majority of mammograms in that study were film-screen, the study population was limited to women residing in Vermont, and women were categorized into ten-year age groups. We sought to further examine screening mammography performance among older U.S. women focusing on digital mammography, using five-year age categories in a national sample. Our goal was to evaluate the performance (sensitivity, specificity, positive predictive value), cancer detection rate (CDR), and recall rate, as well as the tumor pathology (cancer type, stage, grade, size) of digital screening mammography among older women. In this work, “older women” refers to women aged 65 and older.

MATERIALS AND METHODS

Study Population

Funded through the National Cancer Institute, the Breast Cancer Surveillance Consortium (BCSC) is a collection of population-based breast imaging registries from across the U.S.[8] Briefly, self-report and breast imaging data are obtained prospectively and are linked with pathology and tumor registry data for cancer outcomes. We included BCSC data from New Hampshire, North Carolina, San Francisco, Washington state, and Vermont. Each registry site has IRB approval, obtains active or passive consent, and adheres to strict confidentiality procedures to protect the identities of participating women, physicians and facilities.

We identified 296,496 digital screening mammograms from 2005 to 2011 among 133,042 women ages 65 years and older. A screening mammogram was defined as a two-view bilateral mammogram performed for routine screening. To exclude mammograms likely performed for diagnostic purposes, we only included a mammogram if it occurred at least 9 months after previous mammography. We excluded women with a personal history of breast cancer or breast implants. The unit of analysis was the mammogram; hence, women could contribute multiple examinations to the study. The analysis was restricted to women who had a previous mammogram.

Personal and Mammographic Characteristics

At the time of mammography, women self-reported demographic information on race, Hispanic ethnicity, and date of birth; history of breast surgery or biopsy, personal history of breast cancer, family history of breast cancer, breast implants, and use of hormones. Time since previous mammography was determined using information from the BCSC database and self-report. Age at screening was categorized into 65–69, 70–74, 75–79, 80–84, and ≥ 85 years.

During each visit, the radiologist recorded information regarding the reason for the visit (screening, diagnostic, continued work-up, short-term follow-up, biopsy, or other), the tests performed (mammography, ultrasound, MRI, CT, nuclear medicine, or other), and whether the mammogram was film-screen or digital. We used the American College of Radiology Breast Imaging Reporting and Data System (BI-RADS®) Atlas, Fifth Edition,[9] for the coding of breast density and screening assessment. Breast density was classified as extremely dense, heterogeneously dense, scattered fibroglandular densities, or almost entirely fatty. Based on the interpretation assigned by the radiologist using the BI-RADS® lexicon, screening assessment codes were 0=needs further evaluation; 1=normal; 2=benign finding; 3=probably benign; 4=suspicious abnormality; and 5=suspicious for cancer [10]. Follow-up recommendations included return for routine visit (1 year), short-term follow-up, or immediate work-up.

Mammography data were linked to breast pathology data and regional cancer registry data at each BCSC site. Tumor data included pathologic type (in situ or invasive), stage, grade, size, and lymph node status. For this analysis, the follow-up period for cancer diagnosis was one year or until the subsequent screen, whichever occurred first. In order to determine the performance of mammography, each screening mammogram was classified as true positive (TP), false negative (FN), true negative (TN), or false positive (FP) according to the initial assessment code assigned by the radiologist and the recommended management and the cancer outcome at the end of the follow-up period. A positive mammogram was one that had a BI-RADS® assessment code of 0, 4, or 5, or a 3 with recommendation for immediate follow-up. A positive mammogram was considered to be TP when there was a diagnosis of ductal carcinoma in situ (DCIS) or invasive breast carcinoma during follow-up. A positive mammogram was considered to be FP when no cancer was diagnosed during follow-up. A negative mammogram was one that had an assessment code of 1 or 2 or a 3 without a recommendation for immediate follow-up. A negative mammogram was TN if no cancer was diagnosed during follow-up and FN if cancer was diagnosed during follow-up. These classifications are in accordance with standard definitions.[6]

Statistical Analysis

We evaluated the distribution of characteristics of women at screening by age group. We calculated recall rates and the performance measures of sensitivity, specificity, positive predictive value of screening, and the CDR.[11] We also examined each performance measure by breast density. Because few older women had extremely dense breasts (BI-RADS category of 4), we collapsed BI-RADS categories 3 and 4 to create three density categories (almost entirely fat, scattered fibroglandular densities, and a combined category that included both heterogeneously dense and extremely dense) for the analyses.

For each performance measure, the recall rate, and the CDR we fit a logistic regression model using generalized estimating equations (GEE) to account for correlation among observations from the same mammography reader. Each model was adjusted for BCSC site, race/ethnicity, family history of breast cancer, breast density, history of breast procedure, current hormone therapy use, time since previous mammogram, and examination year. For women diagnosed with breast cancer during follow-up, we describe the characteristics of the breast tumors including extent of disease (in-situ versus invasive), and, among invasive cancers, late stage (IIB-IV), grade, size (<10, 10–19, or ≥20 mm), and nodal status. We report p-values for linear trend by age group using logistic regression (for extent of disease, late stage, and nodal status) or ordinal logistic regression (for grade and size), adjusted for BCSC site. Analyses were performed with Stata 13.1 (StataCorp. 2013. Stata Statistical Software: Release 13. College Station, TX).

RESULTS

Descriptive Characteristics of Study Population

Approximately 37% (n=110,096) of digital screening examinations were in women ages 65–69 years (Table 1). The majority of exams were in white women, with no family history of breast cancer, no history of a breast procedure, and not taking hormone medication. History of having a breast procedure decreased slightly with age. Current hormone therapy use was highest in those ages 65–69 years (12.4%) and decreased to 7.6% in those ages 85 and older. Very few women ages 65 and older (less than 3% of our study population) had extremely dense breasts. Approximately 75% of women had a prior mammogram within 9–17 months.

Unadjusted Performance Measures by Age Group and Breast Density

A total of 23,505 of the 296,496 mammograms included in this study were positive with 21,561 false positives and 1,944 true positives (Table 2). Among the 272,991 negative mammograms, 272,733 were true negatives and 258 were false negatives. The breakdown of the false positives, true positives, true negatives, and false negatives by age group are shown online (Supporting Information Table SI1).

The overall recall rate was 7.9% (95%CI:7.8%–8.0%) and decreased with advancing age from 8.4% (95%CI:8.3–8.6%) among women ages 65–69 years to 7.3% (95%CI:6.9%–7.8%) in women ages 85 and older (Table 3). Recall rates were lowest in women with almost entirely fat breast density across all age groups. The overall sensitivity was 88.3% (95%CI:86.9%–89.6%) and did not vary by age group, either overall or by breast density.

The specificity was 92.7% (95%CI:92.6%–92.8%) overall, and increased with age from 92.1% (95%CI:91.9%–92.3%) among ages 65–69 to 93.5% (95%CI:93.1–93.8%) among ages 85 and older. The specificity tended to increase by a small amount with age within breast density groups. The overall PPV_1 was 8.3% (95%CI:7.9%–8.6%) and increased with age from 7.1% (95%CI:6.6%–7.6%) in those 65–69 years to 11.7% (95%CI:9.9%–13.7%) in those ages 85 and older. Increases in PPV_1 by age group were also seen within breast density categories. The overall CDR per 1000 examinations was 6.6 (95%CI:6.3–6.9) and increased with age from 6.0/1000 at 65–69 years to 8.6/1000 at age 85 and older. Within density categories the CDR also tended to increase with age.

Adjusted Performance Measures by Age Group

We compared the performance measures by age group using 65–69 years as the referent category and adjusting for BCSC site, race/ethnicity, family history of breast cancer, breast density, history of breast procedure, current hormone therapy use, time since previous mammogram, and examination year (Table 4). There was a significant decrease in recall rate for those ages 75–79 years (adjusted OR=0.93, 95%CI:0.88–0.99), 80–84 (adjusted OR=0.86, 95%CI:80–0.92) and 85+ (adjusted OR=0.79, 95%CI:0.71–0.89) compared to ages 65–69 years (p-value for linear trend by age group <0.001). There was no significant linear trend in sensitivity by age group. After adjustment, specificity, PPV_1, and CDR was usually significantly higher in the older age groups compared to ages 65–59. As age increased the specificity, PPV1, and CDR increased linearly (p-value for trend <0.001, <0.001, and 0.01, respectively).

Pathologic Characteristics by Age Group

In one-year of follow-up, 502 ductal carcinomas in-situ and 1,700 invasive cancers were diagnosed (Table 5). The proportion of cancers that were invasive increased from 75.8% in the 65–69 year group to 80.9% in the 85 and older age group (p-value for linear trend by age group = 0.02). Among invasive cancers, women ages 65–69 and 70–74 had approximately 18–19% of cancers diagnosed at a late stage whereas women ages 75 and older had 13–15% of cancers diagnosed at a late stage. Approximately 32% of invasive cancers were grade 1, 46.5% were grade 2, and 21.3% were grade 3. Although the p-value for linear trends for grade was statistically significant, there was not a smooth trend of grade with age. Tumor size did not show systematic variation by age; overall, 30.4% were <10 mm, 38.9% 10 to 19 mm, and 30.7% 20+ mm. The proportion of women with positive nodes decreased with age from 21.5% in those 65–69 years to 10.6% in those ages 85 and older (p-value for linear trend <0.001).

DISCUSSION

In our study evaluating the performance of digital screening mammography in women ages 65 and older, we found that performance, except for sensitivity, improved with age. Sensitivity, which is largely influenced by small numbers, did not vary by age. Interestingly, the recall rate, specificity, and PPV_1 all improved as age increased even when stratified by breast density. Studies have shown that women with fatty breast tissue have improved sensitivity compared to women with dense breasts.[12–17] Consistent with previous studies

[18–21], we found that specificity, PPV_1, and recall rates also improved with age. In addition, our adjusted models show significant improvement in the recall rate, specificity, PPV_1, and CDR with increased age. These findings suggest that age and density both impact these measures and that the somewhat higher proportion of fatty breast tissue in the oldest women is not driving the performance differences we observe by age.

A 2011 study of mammography performance in older white women in Vermont,[7] reported sensitivity, specificity, positive predictive value, negative predictive value and CDR by decade of age and found that accuracy improves with age, suggesting that there may be value in screening older women of all age groups. The majority of examinations included in the Vermont study were film-screen and the study pooled first and subsequent mammograms while we restricted our analysis to digital subsequent mammograms. Over the last decade, mammography screening in the U.S. has transitioned from film-screen to digital with approximately 95% of current U.S. accredited mammography machines being digital.[22] Our findings are in agreement with those of the Vermont study.

We also evaluated tumor characteristics in older women. Among the pathologic characteristics of the breast tumors that we examined, cancer type (DCIS versus invasive), grade, and lymph node involvement were associated with age. A lower proportion of cancers were DCIS among those ages 80 and older compared with those 65–79 years, which is in line with the general trend of DCIS representing a lower proportion of cancers among those ages 65 and older versus those ages 40–64 (17.0% versus 22.1%, respectively).[2] Women ages 75 and older had higher proportions of grade 1 tumors and less lymph node involvement compared to women ages 65 to 74 years. Prior studies found that as women aged, they were more likely to have early stage, low-grade tumors compared to late stage, high-grade tumors, and were more likely to have tumors that were ER or PR positive and less likely to have nodal involvement.[23–29] We were unable to evaluate ER and PR status in our study due to missing data.

Although our data show that recall, specificity, PPV_1, and CDR improve with age other considerations, including the impact of comorbidity, health habits and the life expectancy of the aging population, need to be taken into account.[30,31] Several prior studies have suggested that mammography screening in older women creates substantial overdiagnosis of breast cancer. Mandelblatt et al. define overdiagnosis as the finding of cancer that grows so slowly that it would not become clinically noticeable before the patient died from some other cause.[32] Since DCIS does not directly lead to mortality and only an estimated 10–15% of DCIS becomes invasive disease, DCIS is often considered a proxy for overdiagnosis.[33] In our study, 22.8% of cancers were DCIS, and the proportion decreased with increasing age. The ACS reports that among women ages 50–64 years diagnosed with breast cancer in 2013, the estimated proportion with DCIS is 24.1%. Because our older population of women with cancer does not include an unusually high proportion with DCIS, we do not expect more DCIS-related overdiagnosis in older versus younger women.

Strengths of our study include the large sample size, the racial/ethnic diversity of our population, and the representation of digital screening mammography data from community practice. By linking with population-based cancer registry and pathology data we are able to follow mammograms for outcomes and ascertain tumor characteristics. Unfortunately we lacked sufficient data on tumor characteristics such as ER, PR, and HER2 and were unable to evaluate these markers.

We provide data demonstrating that as women age beyond 65 years, the recall rate, specificity, PPV_1, and CDR of digital screening mammography generally improve. A high proportion (77%) of breast cancers were invasive, with 16.5% of these diagnosed at a late stage. As the number of older women increases and life expectancy continues to improve, the question of breast cancer screening after age 65 gains importance. Our results suggest that the benefit of screening mammography in older women is likely as high as in younger women, with similar or lower risk of overdiagnosis. Future research should focus on developing life expectancy-based screening strategies to optimize and personalize breast cancer screening decisions [34], to establish which older women should be screened and how often.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1

Characteristics of women at the digital screening mammography by age group

Characteristic	Age Group											
	65–69 (N=110,096)		70–74 (N=78,985)		75–79 (N=57,488)		80–84 (N=33,950)		85+ (N=15,977)		Total (N=296,496)	
	N	%	N	%	N	%	N	%	N	%	N	%
Race/ethnicity												
White	76,956	75.3	53,612	73.8	38,960	75.3	23,123	78.7	10,648	81.3	203,299	75.6
Black	6,735	6.6	4,926	6.8	3,403	6.6	1,661	5.7	779	6.0	17,504	6.5
Asian or Pacific Islander	13,716	13.4	10,889	15.0	7,521	14.5	3,676	12.5	1,291	9.9	37,093	13.8
American Indian	190	0.2	139	0.2	62	0.1	37	0.1	13	0.1	441	0.2
Hispanic	3,283	3.2	2,186	3.0	1,323	2.6	618	2.1	229	1.8	7,639	2.8
Other or mixed	1,379	1.4	873	1.2	478	0.9	268	0.9	132	1.0	3,130	1.2
missing	*7,837*	*7.1*	*6,360*	*8.1*	*5,741*	*10.0*	*4,567*	*13.5*	*2,885*	*18.1*	*27,390*	*9.2*
Family history of breast cancer												
No	90,449	82.9	64,379	82.2	46,387	81.2	27,001	80.0	12,476	78.6	240,692	81.8
Yes	18,724	17.2	13,916	17.8	10,736	18.8	6,753	20.0	3,394	21.4	53,523	18.2
missing	*923*	*0.8*	*690*	*0.9*	*365*	*0.6*	*196*	*0.6*	*107*	*0.7*	*2,281*	*0.8*
BI-RADS breast density*												
Almost entirely fat	15,253	16.4	11,133	16.7	8,025	16.5	4,714	16.2	2,053	15.1	41,178	16.4
Scattered fibroglandular	46,970	50.4	35,053	52.5	25,830	53.2	15,900	54.7	7,355	54.1	131,108	52.2
Heterogeneously dense	27,988	30.0	18,885	28.3	13,402	27.6	7,737	26.6	3,731	27.5	71,743	28.6
Extremely dense	3,057	3.3	1,649	2.5	1,259	2.6	717	2.5	455	3.4	7,137	2.8
missing	*16,828*	*15.3*	*12,265*	*15.5*	*8,972*	*15.6*	*4,882*	*14.4*	*2,383*	*14.9*	*45,330*	*15.3*
History of breast procedure												
No	75,975	72.8	54,148	72.6	39,928	73.5	23,678	73.9	11,370	75.4	205,099	73.1
Yes	28,395	27.2	20,466	27.4	14,436	26.6	8,362	26.1	3,718	24.6	75,377	26.9
missing	*5,726*	*5.2*	*4,371*	*5.5*	*3,124*	*5.4*	*1,910*	*5.6*	*889*	*5.6*	*16,020*	*5.4*
Current HT use												
No	81,975	87.6	58,672	89.4	43,620	91.2	26,099	91.7	12,422	92.4	222,788	89.5

Characteristic	Age Group											
	65–69 (N=110,096)		70–74 (N=78,985)		75–79 (N=57,488)		80–84 (N=33,950)		85+ (N=15,977)		Total (N=296,496)	
	N	%	N	%	N	%	N	%	N	%	N	%
Yes	11,575	12.4	6,927	10.6	4,209	8.8	2,373	8.3	1,021	7.6	26,105	10.5
missing	*16,546*	*15.0*	*13,386*	*17.0*	*9,659*	*16.8*	*5,478*	*16.1*	*2,534*	*15.9*	*47,603*	*16.1*
Time since previous examination, months												
9–17	79,214	74.1	58,904	76.3	43,366	76.9	25,237	75.9	11,649	74.7	218,370	75.5
18–29	18,110	16.9	11,705	15.2	8,138	14.4	4,820	14.5	2,201	14.1	44,974	15.5
30–41	4,670	4.4	3,496	4.5	2,536	4.5	1,564	4.7	811	5.2	13,077	4.5
42+	4,922	4.6	3,097	4.0	2,348	4.2	1,620	4.9	944	6.1	12,931	4.5
missing	*3,180*	*2.9*	*1,783*	*2.3*	*1,100*	*1.9*	*709*	*2.1*	*372*	*2.3*	*7,144*	*2.4*

*BI-RADS density = Breast Imaging Reporting and Data System breast density categories defined as: 1=almost entirely fatty, 2=scattered fibroglandular densities 3=heterogeneously dense and 4=extremely dense

Table 2

Number of true positives, false positives, false negatives, and true negatives

		Cancer diagnosis within 1 year of mammogram?		
		Yes	**No**	**Total**
Mammogram result	Positive	1,944	21,561	23,505
	Negative	258	272,733	272,991
	Total	2,202	294,294	296,496

Table 3

Performance measures and 95% confidence intervals (95% CI) by age group and breast density

Performance measure	Age Group					
	65–69 Rate (95%CI)	70–74 Rate (95%CI)	75–79 Rate (95%CI)	80–84 Rate (95%CI)	85+ Rate (95%CI)	Total Rate (95%CI)
Recall Rate (%)						
Overall	8.4 (8.3, 8.6)	7.9 (7.7, 8.0)	7.5 (7.3, 7.7)	7.5 (7.2, 7.8)	7.3 (6.9, 7.8)	7.9 (7.8, 8.0)
BI-RADS density*						
1	5.4 (5.1, 5.8)	5.4 (5.0, 5.9)	5.2 (4.8, 5.8)	4.8 (4.2, 5.4)	4.9 (4.0, 5.9)	5.3 (5.1, 5.5)
2	8.6 (8.4, 8.9)	8.3 (8.0, 8.6)	8.1 (7.8, 8.5)	7.9 (7.5, 8.3)	7.5 (6.9, 8.1)	8.3 (8.1, 8.4)
3 or 4	10.4 (10.0, 10.7)	9.4 (9.1, 9.9)	8.8 (8.3, 9.2)	9.2 (8.6, 9.8)	8.1 (7.3, 9.0)	9.6 (9.4, 9.8)
Sensitivity (%)						
Overall	88.7 (86.2, 90.9)	88.3 (85.4, 90.8)	88.1 (84.7, 91.0)	88.1 (83.6, 91.7)	87.3 (81.0, 92.0)	88.3 (86.9, 89.6)
BI-RADS density*						
1	95.3 (86.9, 99.0)	92.2 (81.1, 97.8)	94.0 (83.5, 98.7)	93.8 (69.8, 99.8)	94.1 (71.3, 99.9)	93.9 (89.7, 96.8)
2	89.4 (85.4, 92.6)	89.7 (85.3, 93.1)	89.5 (84.3, 93.5)	91.6 (85.1, 95.9)	88.1 (77.8, 94.7)	89.7 (87.5, 91.5)
3 or 4	85.7 (80.4, 89.9)	83.0 (76.6, 88.3)	83.2 (75.5, 89.3)	80.7 (70.6, 88.6)	86.4 (72.6, 94.8)	83.9 (80.9, 86.7)
Specificity (%)						
Overall	92.1 (91.9, 92.3)	92.8 (92.6, 92.9)	93.2 (93.0, 93.4)	93.2 (92.9, 93.4)	93.5 (93.1, 93.8)	92.7 (92.6, 92.8)
BI-RADS density*						
1	94.9 (94.6, 95.3)	95.0 (94.5, 95.4)	95.3 (94.8, 95.8)	95.5 (94.9, 96.1)	95.8 (94.9, 96.7)	95.1 (94.9, 95.3)
2	91.9 (91.7, 92.2)	92.3 (92.0, 92.6)	92.5 (92.2, 92.8)	92.8 (92.3, 93.2)	93.2 (92.6, 93.8)	92.3 (92.2, 92.5)
3 or 4	90.2 (89.8, 90.5)	91.2 (90.8, 91.6)	91.9 (91.4, 92.3)	91.5 (90.9, 92.1)	92.7 (91.8, 93.5)	91.0 (90.8, 91.2)
PPV_1 **(%)**						
Overall	7.1 (6.6, 7.6)	8.4 (7.7, 9.1)	9.2 (8.3, 10.1)	9.3 (8.2, 10.5)	11.7 (9.9, 13.7)	8.3 (7.9, 8.6)
BI-RADS density*						
1	7.3 (5.7, 9.3)	7.8 (5.8, 10.2)	11.2 (8.3, 14.6)	6.6 (3.8, 10.7)	15.8 (9.3, 24.4)	8.5 (7.4, 9.8)
2	6.8 (6.1, 7.7)	8.1 (7.1, 9.1)	8.2 (7.0, 9.4)	8.7 (7.2, 10.4)	10.7 (8.2, 13.6)	7.8 (7.3, 8.4)
3 or 4	6.1 (5.3, 7.0)	7.3 (6.2, 8.6)	8.1 (6.7, 9.7)	8.6 (6.7, 10.8)	11.1 (8.0, 15.0)	7.2 (6.7, 7.9)

Performance measure	Age Group					
	65–69 Rate (95%CI)	70–74 Rate (95%CI)	75–79 Rate (95%CI)	80–84 Rate (95%CI)	85+ Rate (95%CI)	Total Rate (95%CI)
CDR (per 1000 exams)						
Overall	6.0 (5.5, 6.5)	6.6 (6.0, 7.2)	6.8 (6.2, 7.5)	7.0 (6.1, 7.9)	8.6 (7.2, 10.1)	6.6 (6.3, 6.9)
BI-RADS density*						
1	4.0 (3.1, 5.1)	4.2 (3.1, 5.6)	5.9 (4.3, 7.8)	3.2 (1.8, 5.2)	7.8 (4.5, 12.6)	4.5 (3.9, 5.2)
2	5.9 (5.2, 6.6)	6.7 (5.8, 7.6)	6.6 (5.7, 7.7)	6.9 (5.6, 8.3)	8.0 (6.1, 10.3)	6.5 (6.1, 6.9)
3 or 4	6.3 (5.5, 7.3)	6.9 (5.8, 8.1)	7.1 (5.8, 8.6)	7.9 (6.1, 10.1)	9.1 (6.4, 12.4)	6.9 (6.4, 7.6)

*BI-RADS density = Breast Imaging Reporting and Data System breast density categories defined as: 1=almost entirely fatty, 2=scattered fibroglandular densities 3=heterogeneously dense and 4=extremely dense

Table 4

Adjusted odds ratios (aOR) and 95% confidence intervals (95% CI) for performance measures, recall rate, and cancer detection rate of digital screening mammography by age group

	Age Group					
Performance Measure	**65–69**	**70–74 aOR* (95% CI)**	**75–79 aOR (95% CI)**	**80–84 aOR (95% CI)**	**85+ aOR (95% CI)**	**p-value for trend**
Recall Rate	Referent	0.96 (0.92, 1.01)	0.93 (0.88, 0.99)	0.86 (0.80, 0.92)	0.79 (0.71, 0.89)	<0.001
Sensitivity	Referent	1.02 (0.60, 1.71)	0.79 (0.48, 1.31)	0.69 (0.39, 1.23)	0.84 (0.42, 1.65)	0.17
Specificity	Referent	1.06 (1.01, 1.11)	1.09 (1.03, 1.16)	1.18 (1.10, 1.27)	1.34 (1.19, 1.50)	<0.001
PPV_1**	Referent	1.24 (1.06, 1.45)	1.33 (1.13, 1.56)	1.25 (0.99, 1.56)	1.91 (1.45, 2.51)	<0.001
CDR***	Referent	1.18 (1.02, 1.37)	1.21 (1.04, 1.40)	1.07 (0.86, 1.33)	1.46 (1.13, 1.90)	0.01

* aOR = odds ratio adjusted for registry site, race/ethnicity, family history of breast cancer, breast density, history of breast procedure, current hormone therapy use, time since previous mammogram, and examination year.

** PPV_1 = Positive predictive value

*** CDR = cancer detection rate per 1000 examinations

Table 5

Pathologic characteristics of cancers in women screened with digital mammography by age group

Characteristic	Age Group										Total		
	65–69		70–74		75–79		80–84		85+				
	N	%	N	%	N	%	N	%	N	%	N	%	p-value*
Cancer Type													0.02
DCIS	180	24.2	144	24.5	99	22.2	49	18.3	30	19.1	502	22.8	
Invasive	563	75.8	444	75.5	347	77.8	219	81.7	127	80.9	1,700	77.2	
Among invasive cancers:													
Late stage (IIB–IV)	99	18.1	81	18.8	44	13.0	33	15.3	16	13.1	273	16.5	0.14
missing	*16*	*2.8*	*14*	*3.2*	*8*	*2.3*	*4*	*1.8*	*5*	*3.9*	*47*	*2.8*	
Grade													0.02
1	157	29.8	122	29.8	116	34.7	81	38.9	38	32.5	514	32.2	
2	243	46.1	188	46.0	168	50.3	91	43.8	52	44.4	742	46.5	
3	127	24.1	99	24.2	50	15.0	36	17.3	27	23.1	339	21.3	
missing	36	6.4	35	7.9	13	3.7	11	5.0	10	7.9	105	6.2	
Size (mm)													0.96
<10	162	29.9	141	33.0	92	27.2	67	31.2	38	30.7	500	30.4	
10 to 19	204	37.7	149	34.9	161	47.6	81	37.7	45	36.3	640	38.9	
20+	175	32.4	137	32.1	85	25.2	67	31.2	41	33.1	505	30.7	
missing	*22*	*3.9*	*17*	*3.8*	*9*	*2.6*	*4*	*1.8*	*3*	*2.4*	*55*	*3.2*	
Positive nodes	118	21.5	91	20.9	56	16.3	30	13.8	13	10.6	308	18.4	<0.001
missing	*13*	*2.3*	*8*	*1.8*	*3*	*0.9*	*2*	*0.9*	*4*	*3.1*	*30*	*1.8*	

* P-value from test of linear trend by age group