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## Performance of digital screening mammography in a population-based cohort of black and white women

**Louise M. Henderson<sup>1,2</sup>, Thad Benefield<sup>1</sup>, Sarah J. Nyante<sup>1</sup>, Mary W. Marsh<sup>1</sup>, MikaelAnne Greenwood-Hickman<sup>1</sup>, and Bruce F. Schroeder<sup>1,3,4</sup>**<sup>1</sup>Department of Radiology, The University of North Carolina, Chapel Hill, NC<sup>2</sup>Department of Epidemiology, The University of North Carolina, Chapel Hill, NC<sup>3</sup>Carolina Breast Imaging Specialists, Greenville, NC<sup>4</sup>Departments of Radiology and Oncology, The Brody School of Medicine at East Carolina University, Greenville, NC

### Abstract

**Purpose**—There is scarce information on whether digital screening mammography performance differs between black and white women.

**Methods**—We examined 256,470 digital screening mammograms performed from 2005–2010 among 31,654 black and 133,152 white Carolina Mammography Registry participants aged 40 years. We compared recall rate, sensitivity, specificity, and positive predictive value (PPV<sub>1</sub>) between black and white women, adjusting for potential confounders using random effects logistic regression.

**Results**—Breast cancer was diagnosed in 276 black and 1,095 white women. Recall rates were similar for blacks and whites (8.6% vs. 8.5%), as were sensitivity (83.7% vs. 82.4%), specificity (91.8% vs. 91.9%) and PPV<sub>1</sub> (4.8% vs. 5.3%) (all p-values>0.05). Stratified and adjusted models showed similar results. Despite comparable mammography performance, tumors diagnosed in black women were more commonly poorly differentiated and hormone receptor-negative.

**Conclusion**—Equivalent performance of digital screening mammography by race suggests that efforts to understand tumor disparities should focus on etiologic factors that influence tumor biology.

### Keywords

screening mammography; disparities; sensitivity; specificity; positive predictive value; breast cancer

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Correspondence: Louise M. Henderson, Department of Radiology, The University of North Carolina, Chapel Hill, NC, Tel. 919-843-7799, Fax. 919-966-0525, Louise\_Henderson@med.unc.edu.

### Conflict of Interest

The authors declare that they have no conflict of interest.

### Ethical Approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

## Introduction

Black women experience higher breast cancer mortality rates than white women and typically present with more aggressive tumors and worse prognosis, even after taking stage at diagnosis into account.[1] Mammography screening is commonly associated with the diagnosis of smaller, earlier stage tumors, suggesting that racial differences in screening-related tumor detection may influence racial differences in the tumor characteristics. Only one prior study assessed differences in screening mammography performance among blacks and whites; however, that study was limited to film-screen mammography, which has largely been replaced with digital mammography in the United States.[2] Compared with film-screen mammography, digital mammography detects more ductal carcinoma *in situ* (DCIS)[3] and has improved performance among women with dense breasts, ages <50 years, or who are premenopausal.[4] Age-specific breast cancer rates and mammographic density vary between black and white women, [5–7] but it is unknown whether there are any racial differences in digital mammography screening performance. Hence, we sought to determine if digital screening mammography performs equally well in black and white women.

## Methods

### Data Sources

We utilized data from the Carolina Mammography Registry (CMR), a prospective population-based breast imaging registry in 39 counties in North Carolina. This study received Institutional Review Board approval for passive consenting process to enroll participants, link and pool data, and perform analysis. All procedures were Health Insurance Portability and Accountability Act compliant. At the time of the mammogram, women provided information related to demographics and breast health history. For each mammography examination the radiologist recorded the reason for the visit, imaging examination performed, Breast Imaging Reporting and Data System (BI-RADS) breast density [8], BI-RADS mammogram assessment [8], and follow-up recommendations. Patient and radiologist data were linked to breast cancer cases from the North Carolina Central Cancer Registry (NCCCR) and to statewide hospital pathology data. Tumor behavior (*in situ* or invasive), grade, stage at diagnosis, size, nodal status, estrogen receptor (ER) and progesterone receptor (PR) expression were abstracted from NCCCR and pathology reports.

### Study Population and Definitions

In this analysis, we examined all digital screening mammograms performed from 2005 to 2010 among black and white women ages 40 years with no personal history of breast cancer or history of breast augmentation. Screening mammograms were defined as those that were: (i) bilateral; (ii) performed in asymptomatic women; (iii) defined as a “routine screen” by the radiologist; and (iv) >9 months after any prior breast imaging. Positive screening mammograms had an initial BI-RADS assessment code of 0 (needs additional imaging evaluation), 4 (suspicious abnormality), 5 (highly suggestive of malignancy), or 3 (probably benign finding) when the 3 was associated with a recommendation for immediate

follow-up. Negative screening mammograms had an initial BI-RADS assessment of 1 (negative), 2 (benign finding), or 3 with a recommendation for follow-up of >6 months.[9] Positive disease status was defined by diagnosis of DCIS or invasive breast cancer within 12 months of the screening mammogram. Each mammogram was categorized as true positive, false negative, true negative, and false positive according to the BI-RADS assessment and the cancer outcome.

### Statistical Analysis

We computed mammography sensitivity, specificity, positive predictive value (PPV<sub>1</sub>), and recall rate using standard definitions [10] and compared the statistics for black and white women using an F test. We used a random effects logistic regression model to adjust for differences between radiologists interpreting the images and to account for correlated observations within women who had multiple screening examinations during the study period.[11] We adjusted for age at mammogram, rural/urban residence, education, menopausal status, breast density, prior breast biopsy, family history of breast cancer, and time since last screening examination. We present comparisons overall and stratified by age group and BI-RADS breast density (dichotomized into almost entirely fat or scattered fibroglandular densities versus heterogeneously dense or extremely dense). We also compared tumor characteristics by race using the chi-square test, for all cancers and also stratified by true positive or false negative status.

### Results

Of 256,470 digital screening mammograms, 56,239 (21.9%) were performed among black women and 200,231 (78.1%) were performed among white women (Table 1). The majority of women were ages 40–59 years, lived in urban areas, were post-menopausal, had no prior breast biopsy, and no family history of breast cancer. The proportion of black women with some college of higher education was 43.9% compared with 60.1% for white women. BI-RADS breast density of heterogeneously or extremely dense was 40.6% for black women versus 48.0% for white women.

A total of 1,371 breast cancers were diagnosed, including 231 true positives and 45 false negatives among blacks and 902 true positives and 193 false negatives among whites. The number of false positives was 4,607 for blacks and 16,099 for whites. The overall recall rate was 8.5%, sensitivity was 82.6%, specificity was 91.9%, and PPV<sub>1</sub> was 5.1%, similar to digital mammography performance previously reported among women in the Breast Cancer Surveillance Consortium.[12] The recall rate, sensitivity, specificity, and PPV<sub>1</sub> were similar for blacks and whites in both crude (Table 2) and adjusted models (p-values for adjusted rates were 0.1773, 0.4869, 0.3194, and 0.3992, respectively). Furthermore, stratification by age group or breast density did not reveal any differences in performance by race.

Although performance was similar between blacks and whites, black women were diagnosed with significantly higher proportions of DCIS with comedo necrosis (p-value=0.04), poorly differentiated invasive tumors (p-value=0.024), and ER-negative (p-value<0.001) and PR-negative (p-value=0.004) tumors (Table 3). There was limited power to evaluate whether racial differences in tumor characteristics by race differed if the tumor

was detected by mammography or not (true positive versus false negative); however, racial disparities in tumor grade, ER, and PR expression were similar for true positive and false negative tumors.

## Conclusions

Our finding of no difference in the performance of digital screening mammography between black and white women, even after controlling for possible confounders, is in agreement with a previous report of no difference in film-screen mammography performance by race. [2] Although we found the performance was similar, the types of tumors identified by digital screening mammography differed by race. As has been reported in previous studies of film-screen detected breast cancers, black women were more likely to be diagnosed with higher grade tumors among both DCIS and invasive lesions and with ER or PR-negative tumors [1], suggesting that these differences are likely not caused by the rate of screening-related detection. Our study is the first to compare the performance of digital mammography by race and included over 160,000 women with over 1,300 breast cancers. Future work seeking to explain racial differences in tumor characteristics in a screening population should focus on etiologic risk factors that may influence tumor biology.

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**Table 1**

Characteristics of women undergoing digital screening mammography by race, Carolina Mammography Registry 2005–2010

Characteristic	Black Women N=56,239		White Women N=200,231	
	N	%	N	%
Age Group				
40–49	16,391	29.2	52,034	26.0
50–59	18,560	33.0	56,395	28.2
60–69	12,505	22.2	50,868	25.4
70–79	6,815	12.1	31,037	15.5
80+	1,968	3.5	9,897	4.9
Rural/Urban Residence				
Rural	14,238	25.3	58,944	29.4
Urban	41,995	74.7	141,282	70.6
Missing	6	---	5	---
Educational Level				
< High school	3,380	18.8	5,726	7.3
High school graduate	6,717	37.3	25,650	32.6
Some college/technical school	4,574	25.4	24,194	30.8
College graduate	3,318	18.4	23,120	29.4
Missing	38,250	---	121,541	---
Menopausal Status				
Pre or peri menopausal	19,877	35.5	62,131	31.1
Post menopausal	36,162	64.5	137,467	68.9
Missing	200	---	633	---
BIRADS Breast Density*				
Almost entirely fat	4,958	9.2	13,316	7.0
Scattered fibroglandular densities	27,199	50.3	85,963	45.1
Heterogeneously dense	20,063	37.1	79,992	41.9
Extremely dense	1,877	3.5	11,558	6.1
Missing	2,142	---	9,402	---
Prior Breast Biopsy				
Yes	10,637	23.9	46,346	25.9
No	33,954	76.2	132,758	74.1
Missing	11,648	---	21,127	---
Family History of Breast Cancer				
Yes	6,789	12.1	28,168	14.1
No	49,241	87.9	171,643	85.9
Missing	209	---	420	---

\* BI-RADS breast density refers to the Breast Imaging Reporting and Data System

**Table 2**

Unadjusted digital mammography performance in black and white women in the Carolina Mammography Registry, 2005–2010

	Race			
	Black		White	
	%	(95% CI)	%	(95% CI)
<b>All mammograms</b>				
Recall Rate	8.6	(8.4, 8.8)	8.5	(8.4, 8.6)
Sensitivity	83.7	(79.3, 88.1)	82.4	(80.1, 84.6)
Specificity	91.8	(91.5, 92.0)	91.9	(91.8, 92.0)
PPV <sub>1</sub>	4.8	(4.2, 5.4)	5.3	(5.0, 5.6)
<b>Stratified by age at mammogram:</b>				
<i>40–49 years</i>				
Recall Rate	10.9	(10.4, 11.3)	10.9	(10.6, 11.1)
Sensitivity	81.8	(70.4, 93.2)	78.8	(72.4, 85.1)
Specificity	89.3	(88.9, 89.8)	89.3	(89.1, 89.6)
PPV <sub>1</sub>	2.0	(1.4, 2.7)	2.3	(1.8, 2.6)
<i>50–59 years</i>				
Recall Rate	8.3	(7.9, 8.6)	8.3	(8.0, 8.5)
Sensitivity	76.9	(67.6, 86.3)	81.1	(76.3, 86.0)
Specificity	92.0	(91.7, 92.4)	92.1	(91.8, 92.3)
PPV <sub>1</sub>	3.9	(3.0, 4.9)	4.3	(3.8, 4.9)
<i>60–69 years</i>				
Recall Rate	7.5	(7.0, 7.9)	7.7	(7.4, 7.9)
Sensitivity	85.6	(78.6, 92.6)	84.1	(80.3, 88.0)
Specificity	93.2	(92.7, 93.6)	92.9	(92.6, 93.1)
PPV <sub>1</sub>	8.9	(7.1, 10.7)	7.5	(6.6, 8.3)
<i>70 years</i>				
Recall Rate	6.8	(6.3, 7.3)	6.8	(6.6, 7.0)
Sensitivity	91.2	(83.9, 98.6)	83.2	(79.3, 87.2)
Specificity	93.8	(93.3, 94.3)	93.8	(93.6, 94.1)
PPV <sub>1</sub>	8.7	(6.5, 11.0)	10.2	(9.1, 11.3)
<b>Stratified by breast density:</b>				
<i>Almost entirely fat or scattered fibroglandular densities</i>				
Recall Rate	7.4	(7.1, 7.7)	7.1	(7.0, 7.3)
Sensitivity	86.4	(80.9, 91.9)	85.1	(82.0, 88.2)
Specificity	93.0	(92.7, 93.2)	93.3	(93.1, 93.4)
PPV <sub>1</sub>	5.3	(4.4, 6.2)	6.1	(5.6, 6.7)
<i>Heterogeneously dense or extremely dense</i>				
Recall Rate	10.1	(9.7, 10.5)	9.9	(9.7, 10.1)
Sensitivity	80.8	(73.8, 87.9)	79.8	(76.4, 83.2)

	Race			
	Black		White	
	%	(95% CI)	%	(95% CI)
Specificity	90.3	(89.9, 90.7)	90.5	(90.3, 90.7)
PPV <sub>1</sub>	4.4	(3.5, 5.2)	4.7	(4.3, 5.2)

PPV<sub>1</sub> = positive predictive value; CI = confidence interval

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Pathologic characteristics of breast cancers in black and white women in the Carolina Mammography Registry, 2005–2010

Table 3

Pathologic Characteristic	ALL CANCERS				TRUE POSITIVE CANCERS				FALSE NEGATIVE CANCERS						
	N	%*	N	%*	p-value	N	%*	N	%*	p-value	N	%*	N	%*	p-value
<b>Total cancers</b>	276		1,095			231		902			45		193		
<b>Type</b>															
Invasive	201	72.8	840	76.7	0.041	160	69.3	674	74.7	0.093	41	91.1	166	86.0	0.36
Ductal Carcinoma In-Situ	75	27.2	255	23.3		71	30.7	228	25.3		4	8.9	27	14.0	
<b>DCIS</b>															
<b>Grade</b>															
Well differentiated	9	14.8	36	17.4	0.88	9	15.5	30	16.0	0.90	n/a	n/a	n/a	n/a	n/a
Moderately differentiated	25	41.0	80	38.7		24	41.4	71	38.0						
Poorly differentiated	27	44.3	91	44.0		25	43.1	86	46.0						
Missing	14	---	48	---		13	---	41	---						
<b>Histologic Subtype</b>															
Comedo	20	29.0	40	17.6	0.04	19	29.2	35	17.2	0.036	n/a	n/a	n/a	n/a	n/a
Non-Comedo	49	71.0	187	82.4		46	70.8	168	82.8						
Missing	6	---	28	---		6	---	25	---						
<b>Invasive</b>															
<b>Late Stage</b>															
Yes	49	25.3	229	28.4	0.38	37	23.7	176	27.2	0.37	12	31.9	53	33.1	0.86
No	145	74.7	577	71.6		119	76.3	470	72.8		26	68.4	107	66.9	
Missing	7	---	34	---		4	---	28	---		3	---	6	---	
<b>Grade</b>															
Well differentiated	42	22.7	233	30.2	0.024	36	24.7	198	31.9	0.059	6	15.4	35	23.0	0.44
Moderately differentiated	78	42.2	338	43.8		64	43.8	280	45.2		14	35.9	58	38.2	
Poorly differentiated	65	35.1	201	26.0		46	31.5	142	22.9		19	48.7	59	38.8	
Missing	16	---	68	---		14	---	54	---		2	---	14	---	
<b>Size</b>															
<=10 mm	57	28.8	244	29.9	0.47	50	31.9	212	32.4	0.24	7	17.1	32	19.9	0.14

Pathologic Characteristic	ALL CANCERS				TRUE POSITIVE CANCERS				FALSE NEGATIVE CANCERS			
	Black		White		Black		White		Black		White	
	N	%*	N	%*	N	%*	N	%*	N	%*	N	%*
11 – 20 mm	66	33.3	270	33.1	58	36.9	212	32.4	8	19.5	58	36.0
21 – 30 mm	36	18.2	115	14.1	24	15.3	82	12.5	12	29.3	33	20.5
>30 mm	39	19.7	186	22.8	25	15.9	148	22.6	14	34.2	38	23.6
<i>Missing</i>	3	---	25	---	3	---	20	---	0	---	5	---
Nodal status												
Positive	56	30.11	187	24.3	43	28.9	137	22.2	13	35.1	50	32.5
Negative	130	69.89	583	75.7	106	71.1	479	77.8	24	64.9	104	67.5
<i>Missing</i>	15	---	70	---	11	---	58	---	4	---	12	---
Estrogen receptor status												
Positive	127	70.6	624	83.8	105	73.4	512	85.9	22	59.5	112	75.2
Negative	53	29.4	121	16.2	38	26.6	84	14.1	15	40.5	37	24.8
<i>Missing</i>	21	---	95	---	17	---	78	---	4	---	17	---
Progesterone receptor status												
Positive	111	62.0	541	72.8	92	64.8	445	74.9	19	51.3	96	64.4
Negative	68	38.0	202	27.2	50	35.2	149	25.1	18	48.7	53	35.6
<i>Missing</i>	22	---	97	---	18	---	80	---	4	---	17	---

\* Percentages are of the non-missing

n/a = not applicable as the numbers are too small to report