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An Assessment of the Quality of Mammography Care at Facilities Treating Medically Vulnerable Populations

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Abstract

Background—Women in medically vulnerable populations, including racial and ethnic minorities, the socioeconomically disadvantaged, and residents of rural areas, experience higher breast cancer mortality than do others. Whether mammography facilities that treat vulnerable women demonstrate lower quality of care than other facilities is unknown.

Objectives—To assess the quality of mammography women receive at facilities characterized as serving a high proportion of medically vulnerable populations.

Research Design—We prospectively collected self-reported breast cancer risk factor information, mammography interpretations, and cancer outcomes on 1,579,929 screening mammography examinations from 750,857 women, aged 40–80 years, attending any of 151 facilities in the Breast Cancer Surveillance Consortium, between 1998 and 2004. To classify facilities as serving medically vulnerable populations, we used 4 criteria: educational attainment, racial/ethnic minority, household income, and rural/urban residence.

Results—After adjustment for patient-level factors known to effect mammography accuracy, facilities serving vulnerable populations had significantly higher mammography specificity than did other facilities: ie, those serving women who were minorities [odds ratio (OR): 1.32; 95% confidence interval (CI): 1.01–1.73], living in rural areas (1.45; 1.15–1.73), and with lower household income (1.33; 1.05–1.68). We observed no statistically significant differences between facilities in mammography sensitivity.

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A list of the BCSC investigators and procedures for requesting BCSC data for research are provided at: http://breastscreening.cancer.gov/.

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Conclusions—Facilities serving high proportions of vulnerable populations provide screening mammography with equal or better quality (as reflected in higher specificity with no corresponding decrease in sensitivity) than other facilities. Further research is needed to understand the mechanisms underlying these findings.

Keywords

mammography; screening; quality of care; vulnerable populations

Regular screening mammography, the primary strategy to diagnose breast cancer early in its course, is known to decrease morbidity and mortality, and increase the probability of cure.[1,2] For medically vulnerable women—such as racial and ethnic minorities, rural residents, and socioeconomically disadvantaged women—age-adjusted breast cancer mortality is significantly higher than in other populations.[3–6] Such mortality differences are due, in part, to delayed diagnosis from lower screening rates and to disparities in access to quality treatments.[7–12] Less well studied has been whether medically vulnerable populations receive screening mammography of lower quality.

Overall, variation in the quality of screening mammography is well documented.[13] Patient factors such as mammographic breast density, use of hormone therapy, and timing since last mammogram all influence the accuracy of mammography.[14–17] The influences of race and ethnicity are more complicated, because they are associated with both test characteristics[18–21] and breast cancer biology.[4,20,22] Variation in the quality of screening mammography has also been shown to depend on characteristics not only of women but also of radiologists and facilities.[13,23]

The quality of mammography that vulnerable populations receive depends on the quality of mammography that facilities can provide and the proximity of high-quality mammography facilities to vulnerable populations' home or workplace.[23] If vulnerable populations tend to go to facilities that provide lower-quality mammography, they could receive delayed diagnosis—and poorer prognosis at diagnosis.[24–28] The quality of physicians, technicians, and equipment, as well as longer wait-times and delayed follow-up (perhaps through a lack of an automated patient reminder system), might compromise care at facilities that serve vulnerable populations. However, the extent to which women attending facilities that mostly serve medically vulnerable populations receive worse mammography care, compared with those who attend facilities serving less vulnerable populations, has not been considered.

We assessed whether women who attend mammography facilities that serve high proportions of vulnerable patients—defined by race/ethnicity, rural residence, household income, and education—receive mammography of different quality than those serving fewer underserved patients. This analysis evaluates whether the quality of screening mammography depends on the characteristics not only of the individual woman but also of the other women in the population to which she belongs.

Methods

Data Sources

We obtained data from the Breast Cancer Surveillance Consortium (BCSC),[29] a National Cancer Institute-funded collaborative network of 7 mammography registries with linkages to pathology and/or tumor registries. The participating registries include: (1) the Vermont Breast Cancer Surveillance System, (2) the New Hampshire Mammography Network, (3) the San Francisco Mammography Registry, (4) Group Health in western Washington, (5) the Colorado Mammography Project, (6) the Carolina Mammography Registry, and (7) the New Mexico

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Mammography Project. The BCSC population has been shown to be representative of the US population of women with characteristics that are similar to the national demographic characteristics in terms of age, ethnicity, and urban or rural residence.[30] The 7 mammography registries are defined by geographic region and, in general, all facilities in a region participate and are included. Vermont and New Hampshire registries include the entire state, and San Francisco Mammography Registry includes all of San Francisco and Marin counties. Group Health Registry participation is based on Enrollment in Group Health in western Washington. The Colorado Mammography Project consists of the 6-county Denver metropolitan area. The Carolina Mammography Registry includes 39 of 100 counties in North Carolina. New Mexico Mammography Registry includes all facilities in the Albuquerque metropolitan area.

The 7 registries prospectively collect patients' self-reported demographic information and breast cancer risk factor data at each mammography examination, together with radiologists' reports on screening and diagnostic mammography. In addition, the BCSC is linked to 2000 US Census Bureau data based on the women's ZIP codes to obtain population-level sociodemographic information. Registries ascertain cancer outcomes through linkage with state tumor registries or regional Surveillance, Epidemiology, and End Results (SEER) programs as well as linkages to pathology databases at certain mammography registries. At the time of analysis, cancer outcomes were at least 95% complete for mammograms taken through December 2004.[29] Each consortium registry, together with the BCSC Statistical Coordinating Center, has received institutional review board approval for either active or passive consenting processes or a waiver of consent to enroll participants, link data, and perform analytic studies. Linkage procedures are performed in accordance with human subject protocols to maintain participant and facility confidentiality.[30]

Screening Examinations

We defined a screening mammogram as a bilateral examination for which the interpreting radiologist reported the indication of the examination was for screening. We included women aged 40–80 years who had undergone at least 1 screening mammography examination between January 1998 and December 2004. Examinations performed after December 2004 were excluded to ensure at least a 12-month period after the screening examination during which cancer could be diagnosed and for which adequate time was given for reporting cancer. We included diagnostic mammography examinations to develop the overall facility-level vulnerability scores (see below), but we did not include them in the analysis of screening mammography performance, because performance varies by whether examinations are screening or diagnostic.

We excluded the following mammography examinations: those performed within 9 months of a prior breast imaging examination, because these are likely to be diagnostic examinations; those where the women reported prior mammography but did not date the examination and no prior examination was found in the database; mammography from women who had a prior diagnosis of breast cancer, based on self-report or linkage with the cancer registry or pathology databases; those from women who reported breast implants at the time of examination[31]; and those missing a valid Breast Imaging Reporting and Data System (BI-RADS)[32,33] breast density assessment. All analyses were performed using screening examinations as the unit of analysis, and a woman could contribute more than 1 examination to the analysis.

Definition of Screening Mammography Accuracy

A screening mammogram was classified as positive if the initial assessment was incomplete or suspicious for cancer (BI-RADS interpretations 0, 4, or 5) or if the initial assessment was “probably benign” (BI-RADS interpretation 3) but recommended immediate further assessment.[33,34] A negative mammography examination was defined as an examination

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without any findings (category 1) or benign (category 2), or as one for which the initial assessment was a category 3 but where no immediate work-up was recommended. Women were considered to have breast cancer if reports from a breast pathology database, SEER program, or state tumor registry showed any invasive carcinoma or ductal carcinoma in situ within 12 months of a screening examination and before the next screening examination. Sarcomas, lymphomas, and lobular carcinoma in situ were not considered as breast cancer.

Screening mammography examinations were considered true positives if a breast cancer was diagnosed within 12 months of a positive screening mammography examination. True-negative exams were those where no breast cancer was diagnosed within 12 months of a negative screening examination. Sensitivity was calculated from number of true-positive examinations divided by the number of women with breast cancer, and specificity was true-negative examinations divided by the number of women without breast cancer.

Definitions of Vulnerability Indexes

We used 4 sociodemographic characteristics to define a vulnerable population: educational attainment, race/ethnicity, living in rural/urban area, and household income. For educational attainment and race/ethnicity, we used individual-level self-reported information provided at the time of an examination. Using geocoded linkage between 2000 Census data and self-reported residential ZIP code, each screening mammography examination was assigned a rural/urban score corresponding to the percentage of rural residences in their ZIP code, and an income measure corresponding to the median household income in their ZIP code.

For each of the 4 sociodemographic characteristics, we created an index to describe the vulnerability of the population served by any given facility. A continuous facility-level index was calculated by aggregating individual-level characteristics across all mammography examinations (screening and diagnostic) during the 1998–2004 study period. The 4 continuous measures were (1) the percentage of the population with at least a high school education, (2) the percentage of the population composed of minorities (self-reported African American race, or Hispanic/Pacific-Islander/Hawaiian/American Indian ethnicity), (3) the average median household income, and (4) the average percentage of rural residences. We did not include Non-Pacific Islander Asian Americans in the minority index, because their breast cancer mortality rates are lower than that of whites and other minority groups.[18,34]

The continuous measures of vulnerability were then dichotomized to provide a binary vulnerable/not vulnerable classification. The cutoffs for this dichotomized variable were determined by taking 1 standard deviation above the mean study population for the continuous vulnerability score. Specifically, we classified facilities as serving a vulnerable population if (1) the percentage having at least completed high school was <75% (educational attainment); (2) the percentage minority was >30% (race/ethnicity); (3) the average median income was < $40,000 (low income); and (4) the average percentage of rural residences was >75% (rural residence).

We also created a composite score by summing the 4 binary vulnerability indexes; each component index was given equal weighting, so the score ranged from 0 to 4. For the main analyses, a final composite index was generated by classifying those facilities with scores of 0 as serving a “nonvulnerable” populations, 1 or 2 as serving a “moderately vulnerable” population, and 3 or 4 as serving a “vulnerable” population.

For each of the 5 vulnerability indices, the facility-level score was applied to each screening mammography examination, for all women within the facility. The score is therefore a characteristic of the population to which the individual belongs, rather than a characteristic of the individual. So, for example, an individual with high education attainment may attend a mammography facility that serves predominantly less-educated individuals.

To ensure interpretability of the categorizations for the vulnerability of facilities, we also computed yearly scores for all facilities over the 6-year study time period. Facilities exhibiting instability in their scores (changing more than 2 times) were excluded.

Statistical Analysis

We described the frequency of risk factors for breast cancer—including age, mammographic breast density, and time since their last mammography examination—for the study population. We then calculated the unadjusted sensitivity and specificity of screening mammography, stratifying the sample of mammography examinations according to the 4 vulnerability indexes (median income, rural residence, education, and percentage minority), as well as the composite index, outlined above.

Adjusted associations between performance and the 5 facility-level vulnerability indexes were estimated using a logistic-normal mixed-effects model.[35] Each model was specified at the level of the screening mammography examination, with a facility-level random effect introduced to account for clustering of screening mammography examinations within facilities. This framework permitted adjustment for mammography-specific covariates, including registry site, patient age, mammographic breast density, and time since last mammography examination. We performed the analysis at the level of the screening mammography examination to provide an interpretation of the estimated associations in terms of the impact of facility-level characteristics (ie, the vulnerability of the population served) on mammography accuracy at the level of the examination.

For each of the 5 vulnerability indexes, we modeled sensitivity and specificity separately and assessed statistical significance by using likelihood ratio tests. Our statistical analysis accounted for clustering by facility; however, based on computational considerations, we did not include a woman-specific random effect in our models to account for repeated measures across women. The computational challenge arose because of the large number of woman-level clusters (750,857) and the inclusion of several covariates that potentially varied within cluster (ie, age, density, and time since last mammography examination). This may have led to slight underestimation of standard errors, but likely not enough to change the results, given the inclusion of the mammography-level adjustment variables. All statistical analyses were performed in SAS statistical software, version 9.1, using PROC NLMIXED (SAS Institute, Cary, NC).

Sensitivity Analyses

In addition to the main primary analyses, we conducted a series of sensitivity analyses to determine how much our results depended on analysis decisions. For instance, we conducted additional analyses: (1) defining "minority" to include all non-Hispanic white races and ethnicities (ie, including Non-Pacific Islander Asian Americans as a minority); (2) defining the income vulnerability score on the basis of the federal poverty level described in the 2000 US Census Bureau data;[36,37] (3) collapsing the first 2 levels of the composite vulnerability score categorization to form a binary index; (4) extending the cancer follow-up period to 24 months; and (5) expanding the population of women to include women aged 80–89 years in the main analyses.

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Results

We identified 2,418,208 screening mammograms on women aged 40–80 years between January 1998 and December 2004. Overall, 35% were excluded and a given mammogram may have been excluded by multiple criteria. Among those excluded, 11% had evidence of a prior cancer diagnosis, 7% had a prior breast imaging examination in the prior 9 months, 4% were for women with a report of breast implants, 19% were for women reported prior mammography but no date was found in the database, and 68% had missing BI-RADS breast density assessment. Patterns of exclusions did not differ according to the vulnerability indexes.

The study included 1,579,929 screening mammography examinations performed on 750,857 women (Table 1). Across the 3 composite vulnerability categories, most women (54.3%) had at least 2 screening mammograms during the study period, and most examinations (66.1%) were for women aged ≤60 years. Only a small percentage of screening examinations were a woman's first examination (4.6%), whereas most examinations were within a 2-year interval from the prior examination (74.2%). Nonvulnerable facilities had a higher number of BI-RADs 0 (need additional evaluation) and 3 (probably benign finding) ratings than either moderately or vulnerable facilities (10.8%, 8.4%, and 6.4%).

The examinations were performed at 151 facilities; 2 were excluded because of instability of the composite scores over time (Table 2). Based on the composite index, 45 of the 151 facilities (29.8%) were classified as serving either moderately vulnerable or vulnerable populations. Nine of the 151 facilities (5.9%) had composite vulnerability index scores of 3 or 4 and were considered as serving mostly vulnerable women. Of the women in the study, 435,297 (28%) received mammograms at these facilities. Women at the facilities serving the most vulnerable were most likely not to have had a previous mammogram (7.0%) compared with moderately vulnerable (5.9%) and nonvulnerable (4.5%) or to have had one >36 months before (9.7% vs. 9.6% vs. 8.8%).

The overall sensitivity and specificity of screening mammography, across all 1,579,929 examinations from 151 facilities, were 80.9% and 91.2%, respectively (Table 2). The unadjusted sensitivity of screening mammography showed no clear systematic differences between facilities serving vulnerable populations compared with other facilities across the 5 vulnerability indices. In contrast, estimates of the specificity of screening mammography at facilities serving vulnerable populations are consisting higher, by approximately 3%, than those at facilities serving nonvulnerable populations; for example, specificity across all mammograms from 15 facilities classified by the education index as serving a vulnerable population was 93.9% compared with a specificity of 90.9% for the 136 facilities serving nonvulnerable populations. Further the specificity of screening mammography showed evidence of a “dose-response” trend, as the point estimates for the specificity of screening mammography increase monotonically with composite vulnerability index.

Adjusted analyses of sensitivity of screening mammography did not differ systematically across any of the 5 vulnerability indexes (Table 3). Compared with facilities serving less vulnerable populations, facilities serving vulnerable populations had screening mammography examinations with higher adjusted specificity: those with low educational attainment had odds ratio (OR): 1.29 [95% confidence interval (CI): 0.99–1.68; $P = 0.066$], high minority OR: 1.32 (95% CI: 1.01–1.73; $P = 0.038$), predominantly rural OR: 1.45 (95% CI: 1.15–1.82; $P = 0.002$), and low-income populations OR: 1.33 (95% CI: 1.05–1.68; $P = 0.017$). Using the composite vulnerability index, mammography specificity demonstrated an increasing trend with higher specificity for the moderately vulnerable (OR: 1.42; 95% CI: 1.16–1.73) compared with nonvulnerable and even higher specificity for the most vulnerable populations (OR: 1.57; 95% CI: 1.12–2.22).

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The sensitivity analyses suggested the observed associations are robust to a variety of analysis decisions. Defining minority women to include Non-Pacific Islander Asian Americans did not change the results for the sensitivity or specificity of mammography; nor did using poverty (with a cutoff of >15% of the population below the poverty line) to define a "vulnerable population"; nor expanding the analysis to include women aged 80–89 years.

Table 4 provides information on screening interval times according to facility-level vulnerability indexes. Although the median time since last mammogram was shorter at facilities serving medically vulnerable populations (range, across vulnerable facility type, 4–19 days shorter at facilities serving more vulnerable populations), women were more likely to have a previous mammogram at an intervals >36 months (range, 0.4–1.7%) at facilities serving a high proportion of minority, rural, and low-income populations and vulnerable facilities most likely to have mammograms with screening intervals greater than 36 months (vulnerable 9.7% vs. moderately vulnerable 9.6% vs. nonvulnerable 8.5%) or without a prior (vulnerable 7.0% vs. moderately vulnerable 5.9% vs. nonvulnerable 4.1%). Finally, using a 24-month follow-up period to detect breast cancer, the index-specific performance results did not vary from those reported in Table 3.

Discussion

In this study we found no evidence to suggest that women who attend facilities that serve medically vulnerable populations experience a lower quality of screening mammography, as measured by its sensitivity and specificity. In fact, our study demonstrated that the quality of mammography care at facilities serving predominately medically vulnerable women is on average as good if not slightly better than at the rest of the facilities in our sample. Our finding that the specificity of screening mammography is higher (and thus the false positive rate is lower) in facilities serving vulnerable populations has potential clinical and financial implications. Lower false-positive rates translate into lower recall rates and potentially fewer unnecessary diagnostic evaluations and biopsies.

Our study highlights the finding that facilities serving large proportions of vulnerable populations provide high quality of care. The higher specificity of mammography at facilities serving a large proportion of vulnerable women, compared with facilities serving fewer vulnerable women, may be driven, in part, by these facilities facing limited resources although we do not have data on the financial situations of the facilities in the BCSC. Workforce shortages of radiologists[38] and technicians may lead to more outsourcing of radiographic readings to limit the facility volume.[39] As the quality of the readings is attributed to an individual mammogram and therefore the facility where the mammogram is taken, not where it is read, higher quality readings by outside radiologists could contribute to the higher specificity. Limitations in workforce and other critical resources required to perform high-quality mammography may lead in some facilities to rationing of services.[40] The threshold for recalling a patient for additional mammography imaging seems to be raised as the vulnerable facilities are the least likely to score mammograms as "needing additional evaluation" or "probably a benign finding with a recommendation for immediate follow-up". Both categories require additional imaging, and are unlikely to lead to a diagnosis of cancer, potentially explaining the 3% lower false-positive rate compared with facilities serving fewer vulnerable women. As long as a high sensitivity is preserved, changes in practice patterns that decrease recall rates may lead to resource savings without negatively affecting quality.

Since 1992, federal regulations have set minimal quality standards for mammography facility personnel, equipment, and recordkeeping. Periodic updates, most recently in 2002, continue to raise equipment standards.[36,37,41–43] Critics of the regulations remark on the cost burden smaller facilities incur,[44] but our results show minimal differences in outcomes by whether

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the facility is located in an urban or rural area, suggesting that any quality differences in equipment, record-keeping, or personnel are so subtle that they did not influence the accuracy of mammography.

We did not find different sensitivity in screening mammography performed at facilities serving more vulnerable populations. This may be seen as somewhat surprising, because one might expect cancers detected at facilities serving more African Americans to be more aggressive and easier to detect,[45–48] resulting in increased sensitivity. The measures of sensitivity were consistent across facilities that treat these different populations.

This study had several strengths. First, we used a large, well-defined mammography cohort with a clinically rich dataset that links a variety of different data sources: patient surveys, radiographic and pathologic data, as well as Census tract data across 7 geographically dispersed states. By using a hierarchical model adjusting for patient characteristics, we could isolate facility level variability that is not accounted for by differences in these patient characteristics. Our decision to characterize facilities according to 4 different vulnerable measures, together with a composite score, let us provide a broader perspective on the quality of mammography facilities serving a spectrum of vulnerable populations. Finally, our findings are robust to a variety of definitions and assumptions.

Our study had several limitations. We used Census tract data to define facilities serving vulnerable women. Individual financial information, self-reported education, and Census block-geocoding of rural/urban neighborhood could have improved our classification scheme, because some rural areas have only 1 zip code representing both the richest and poorest women in a community. We could not adjust for body mass index or postmenopausal hormone therapy, 2 variables that may influence performance measures, because several participating facilities do not collect this information. However, postmenopausal use of hormone therapy and body mass index may not influence the sensitivity or specificity of screening mammography after adjusting for mammographic breast density.[15] Notably, we are not aware of any cancer reporting bias related to body mass index and postmenopausal hormone therapy. Some of the variability within facilities may have been colinear with site-specific variability as racial/ethnic distribution varies within the 7 BCSC sites. Thus, we decided to control for geographic variability, as practice patterns are known to vary geographically.[49] Finally, this study does not evaluate what happens to women if their mammograms are recalled and whether the follow-up rates for recalled mammograms differ by facility type. This is a critical area for further investigation to assess the true impact of being seen at a “vulnerable” facility.

In conclusion, we found that mammography facilities serving a large proportion of vulnerable women demonstrated a modestly higher specificity than did other facilities potentially explained by a higher threshold to recall patients. We recommend that future research investigate radiology practice patterns and other potential mediators to explain the higher specificity of mammography in facilities serving vulnerable, compared with nonvulnerable, women. Understanding these findings better may help improve the quality of mammography for all women.

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TABLE 1

Screening Mammogram-Level Information by 3-Level Composite Vulnerability Score

	Nonvulnerable (score = 0)		Moderately Vulnerable (score = 1 or 2)		Vulnerable (score = 3 or 4)	
	N	%	N	%	N	%
Total number of unique women	530,835		201,451		18,571	
Mammograms per woman						
1	239,260	45.1	95,981	47.6	7595	40.9
2	115,809	21.8	52,252	25.9	4583	24.7
3 +	175,766	33.1	53,218	26.4	6393	34.4
Total number of mammograms	1,144,632		395,589		39,708	
Age group (yr)						
≤50	412,405	36.0	128,657	32.5	11,188	28.2
51–60	359,247	31.4	120,579	30.5	11,713	29.5
61–70	220,507	19.3	87,243	22.1	9890	24.9
71–80	152,473	13.3	59,110	14.9	6917	17.4
Breast density*						
Almost entirely fat	87,546	7.6	37,547	9.5	2710	6.8
Scattered fibroglandular densities	486,620	42.5	194,502	49.2	22,698	57.2
Heterogeneously dense	480,339	42.0	138,933	35.1	11,589	29.2
Extremely dense	90,127	7.9	24,607	6.2	2711	6.8
Time since last mammogram (mo)						
No previous mammogram	47,153	4.1	23,323	5.9	2777	7.0
12	112,301	9.8	34,498	8.7	2982	7.5
13–24	741,075	64.7	256,104	64.7	25,906	65.2
25–36	147,017	12.8	43,867	11.1	4198	10.6
>36	97,086	8.5	37,797	9.6	3845	9.7
BI-RADS assessment						
1: negative	832,136	72.7	266,377	67.3	29,482	74.2
2: benign finding	185,052	16.2	94,231	23.8	7459	18.8
3: probably benign finding	13,972	1.2	6679	1.7	341	0.9
0: need additional evaluation	105,010	9.2	24,891	6.3	2040	5.1

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	Nonvulnerable (score = 0)		Moderately Vulnerable (score = 1 or 2)		Vulnerable (score = 3 or 4)	
	N	**%**	**N**	**%**	**N**	**%**
3 +: probably benign finding[†]	4593	0.4	1767	0.4	174	0.4
4: suspicious abnormality	3483	0.3	1441	0.4	191	0.5
5: highly suggestive of malignancy	386	0.0	203	0.1	21	0.1

* BI-RADS density classification.

† BIRADS 3 with a recommendation for immediate follow-up.

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TABLE 2

Unadjusted Analyses of the Sensitivity and Specificity of Screening Mammography by Facility-Level Vulnerability Index

Population Vulnerability Index	N	%	Sensitivity	Specificity
No. facilities	151		80.9	91.2
Education				
Nonvulnerable	136	90.1	81.0	90.9
Vulnerable	15	9.9	80.4	93.9
Race/ethnicity				
Nonvulnerable	129	85.4	81.3	90.9
Vulnerable	22	14.6	77.4	93.7
Rural/urban residence				
Nonvulnerable	130	86.1	80.1	91.1
Vulnerable	21	13.9	82.6	92.4
Income				
Nonvulnerable	125	82.8	81.2	90.9
Vulnerable	26	17.2	79.0	93.9
Composite index				
0	106	70.2	81.6	90.4
1	20	13.2	77.9	93.0
2	16	10.6	79.6	93.6
3	4	2.6	83.1	94.2
4	5	3.3	82.8	94.4

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TABLE 3

Results of the Sensitivity and Specificity of Screening Mammography From a Logistic-Normal Mixed Effects Regression Analysis*

	Sensitivity		Specificity	
Population Vulnerability Index	**OR (95% CI)†**	***P*‡**	**OR (95% CI)†**	***P*‡**
Education	1.14 (0.84–1.44)	0.400	1.29 (0.99–1.68)	0.066
Race/ethnicity	0.92 (0.66–1.27)	0.597	1.32 (1.01–1.73)	0.038
Rural/urban residence	1.00 (0.76–1.31)	0.906	1.45 (1.15–1.82)	0.002
Income	1.07 (0.82–1.40)	0.597	1.33 (1.05–1.68)	0.017
Composite		0.124§		0.001§
Moderately vulnerable	0.87 (0.69–1.09)		1.42 (1.16–1.73)	
Vulnerable	1.37 (0.85–2.19)		1.57 (1.12–2.22)	

*Adjusted for mammogram-level study site, age (5-year bands), breast density, and time since previous mammogram.

†"Nonvulnerable" is taken to be the referent group.

‡Based on a likelihood-ratio test which include/excludes single-vulnerability index.

§*P* value for overall composite index, jointly assessing 2 vulnerability levels vs. referent nonvulnerable group.

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TABLE 4

Distribution of Time Between Screening Examinations by Facility-Level Vulnerability Index

		Distribution (%)				
Population Vulnerability Index	**Median Time* (d)**	**None**	**≤12 mo**	**13–24 mo**	**25–36 mo**	**>36 mo**
Education						
Nonvulnerable	438	4.3	9.7	64.5	12.6	8.8
Vulnerable	426	8.1	7.5	65.9	9.9	8.7
Race/ethnicity						
Nonvulnerable	435	4.5	9.6	64.8	12.5	8.6
Vulnerable	437	6.0	8.6	64.4	11.3	9.8
Rural/urban residence						
Nonvulnerable	438	4.6	9.5	64.7	12.5	8.7
Vulnerable	421	5.2	9.5	65.2	10.9	9.3
Income						
Nonvulnerable	436	4.4	9.6	65.0	12.4	8.6
Vulnerable	434	6.6	8.5	63.0	11.5	10.4
Composite						
Nonvulnerable	440	4.1	9.8	64.7	12.8	8.5
Moderately vulnerable	430	5.9	8.7	64.7	11.1	9.6
Vulnerable	423	7.0	7.5	65.2	10.6	9.7

* Based on records for which a prior screening mammogram was self-reported or available in the BCSC database.