Published in final edited form as:
*Med Care*. 2012 March ; 50(3): 210–216. doi:10.1097/MLR.0b013e3182407c8a.

# Facility characteristics do not explain higher false positive rates in diagnostic mammography at facilities serving vulnerable women

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## Abstract

**Background—**Facilities serving vulnerable women have higher false positive rates for diagnostic mammography than facilities serving non-vulnerable women. False positives lead to anxiety, unnecessary biopsies, and higher costs.

**Objective—**Examine whether availability of on-site breast ultrasound or biopsy services, academic medical center affiliation, or profit status explains differences in false positive rates.

**Design—**We examined 78,733 diagnostic mammograms performed to evaluate breast problems at Breast Cancer Surveillance Consortium facilities from 1999-2005. We used logistic-normal mixed effects regression to determine if adjusting for facility characteristics accounts for observed differences in false positive rates.

**Measures—**Facilities were characterized as serving vulnerable women based on the proportion of mammograms performed on racial/ethnic minorities, women with lower educational attainment, limited household income, or rural residence.

**Results—**While the availability of on-site ultrasound and biopsy services was associated with greater odds of a false positive in most models (Odds Ratios (OR) ranging from 1.24 to 1.88; $p< 0.05$), adjustment for these services did not attenuate the association between vulnerability and false positive rates. Estimated odds ratios for the effect of vulnerability indices on false positive rates unadjusted for facility services were: lower educational attainment (OR 1.33; 95% Confidence Intervals (CI) 1.03, 1.74); racial/ethnic minority status (OR 1.33; 95% CI 0.98, 1.80); rural residence (OR 1.56; 95% CI 1.26, 1.92); limited household income (OR 1.38; 95% CI 1.10, 1.73). After adjustment, estimates remained relatively unchanged.

**Conclusions—**On-site diagnostic service availability may contribute to unnecessary biopsies, but does not explain the higher diagnostic mammography false positive rates at facilities serving vulnerable women.

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## Introduction

There is significant variability in diagnostic mammography interpretative performance(1-3). One in fifteen diagnostic mammograms in the United States yields a false positive, a recommendation for biopsy in a woman without cancer(3). False positives lead to anxiety, unnecessary biopsies, and increased healthcare costs(4, 5). Mammography facilities that serve vulnerable women, defined as women with limited income, education, racial/ethnic minorities, or women who live in rural areas, have a 2-3% (absolute) higher false positive rate for diagnostic mammography than facilities that serve non-vulnerable women(6). This represents a 33% relative increase in false positives. The underlying reason for this disparity is unknown.

Characteristics of both women and radiologists can influence diagnostic mammography false positive rates(4). Few studies have evaluated the impact of facility characteristics on false positives(1, 3, 7). Slightly higher diagnostic mammography false positive rates (and sensitivities) are seen at academic centers(4). The use of breast ultrasound is associated with lower false positive rates in screening mammography. No studies have investigated whether facility characteristics explain the higher false positive rates at facilities serving vulnerable women. Facility characteristics such as on-site biopsy or for-profit ownership could represent incentives to increase biopsy referral rates, and thereby influence false positive rates.

We analyzed whether the availability of on-site ultrasound or biopsy, academic affiliation, or profit status accounted for the higher false positive rates at facilities serving predominately vulnerable women in a national cohort of women undergoing diagnostic mammography.

## Methods

Data were pooled from mammography registries in 7 states participating in the National Cancer Institute-funded Breast Cancer Surveillance Consortium (BCSC), shown to be representative of U.S. women undergoing mammography(8). The registries prospectively collect women's self-reported demographic and clinical data at each mammography examination, together with radiologists' mammography interpretations. Registries ascertain cancer outcomes through linkage with state tumor registries, regional Surveillance, Epidemiology, and End Results (SEER) programs, and pathology databases. Additionally, the BCSC collects characteristics of facilities where women underwent mammography. Each registry received IRB approval to enroll participants, link data, and perform analysis. All procedures are Health Insurance Portability and Accountability Act (HIPAA) compliant.

We included examinations from 1999-2005 identified by the radiologist as performed for 'evaluation of a symptomatic breast problem' on women 40-80 years. We excluded examinations from women with a prior diagnosis of breast cancer or history of breast augmentation; missing the time since her previous mammogram; missing a valid Breast Imaging Reporting and Data System (BI-RADS®) final mammography assessment or breast density(9, 10); or performed at a facility with unknown or incomplete vulnerability or facility characteristics.

We classified positive and negative diagnostic examinations by standard BCSC criteria(11). Women had a diagnosis of breast cancer if reports from the cancer sources showed invasive carcinoma or ductal carcinoma *in situ* within 12 months of the diagnostic exam. We calculated the sensitivity, false positive rate, and cancer detection rate using standard BCSC definitions to evaluate diagnostic mammography interpretive performance(14).

We defined vulnerable women by four socio-demographic measures: educational attainment, race/ethnicity, residence in rural/urban area, and household income(6, 12). Self-reported information was used to determine educational attainment and race/ethnicity. Geocoded linkages between 2000 Census data and each woman's self-reported ZIP code were used to determine median household income and percent of rural residences within the ZIP code. To describe the vulnerability of the population served by each facility, we aggregated the patient characteristics for the four vulnerability measures across all mammography examinations (both screening and diagnostic) served by the facility from 1999–2005. For each facility we measured (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/Native American ethnicity), (3) the average median household income, and (4) the average percentage of rural residents. Facilities were assigned a binary indicator of whether they served a vulnerable population (for each of the four categories) based on prior developed cutoffs: if (1) >17% of mammography interpretations were from women who had not completed high school (lower educational attainment); (2) the percentage minority was >30% (racial/ethnic minority); (3) the average median income was <$45,000 (limited income); or (4) the average percentage of rural residences was >52% (rural residence)(7). We constructed a composite vulnerability score by adding one for each of the binary vulnerability indices met(13). We considered four explanatory variables to account for the association between vulnerability and diagnostic false positive rates: whether a facility had breast ultrasound available; availability of on-site biopsy services; academic medical center affiliation; and profit status.

### Analysis

We described the distribution of mammography level and facility level characteristics across vulnerability categories, and calculated unadjusted sensitivity, false positive rates, and cancer detection rates for each vulnerability index. We fit separate logistic-normal mixed effects models(14) with mammography as the unit of analysis for each of the four vulnerability indices (and the composite score) to estimate adjusted odds ratios (OR) and 95% confidence intervals (CI) between each facet of facility-level vulnerability and mammography-level performance (sensitivity, false positive rate, cancer detection rate), adjusted for patient-level covariates only (study site, age, time since previous mammography, and BI-RADS breast density (1)), and incorporated facility-level random effects to account for clustering of examinations within facility. Because we found significant associations ($p<0.05$) between most vulnerability measures and only false positive rates, we refit the models for this outcome adjusting for patient characteristics listed above and for possible mediating facility characteristics. The goal of these fully adjusted models was to assess whether associations between vulnerability and false positive rates were attenuated by adjusting for facility characteristics. Each of these facility characteristics were added to the model separately because one site did not collect profit status (N = 12), and then simultaneously as a sensitivity analysis. We reported ORs and 95% CIs for the association between false positive rates and each of the vulnerability measures, as well as each of the facility characteristics. We also tested for an interaction ($\alpha=0.05$) between the 4 vulnerability indices and the 4 facility characteristics. We then conducted post-hoc descriptive analyses of the facilities without ultrasound to characterize these facilities further. Adjusted performance measures were estimated using marginal standardization.(15, 16) Models were fit using SAS software, version 9.2 (SAS Institute, Inc., Cary, NC).

## Results

Overall 78,733 diagnostic mammography examinations performed among 69,161 women at 139 facilities were included (Table 1). Sixty-one percent of all mammography examinations occurred at facilities serving non-vulnerable women; 26.9% occurred at facilities classified as serving moderately vulnerable women; and 12.1% occurred at facilities classified as serving highly vulnerable women. Facilities serving vulnerable women were more likely to serve older and less frequently screened women. Most facilities had on-site ultrasound services (89.9%) (Table 2). The majority provided biopsy services (61.2%). Only 10.1% were affiliated with an academic medical center. Of the 91% that reported ownership status, 32.3% were for-profit. Facilities serving vulnerable women were more likely to have ultrasound and biopsy services available and were less likely to be for-profit.

In analyses unadjusted for patient or facility characteristics, facilities serving vulnerable women tended to have higher false positive rates across all measures of vulnerability, while sensitivity and cancer detection rates did not differ consistently (Table 3). After adjusting for patient characteristics only, the differences in false positive rates remained ($p < 0.05$ for all vulnerability measures except minority status, $p=0.07$). These adjusted ORs comparing the odds of a false positive between facilities on the basis of the binary vulnerability indices were: lower educational attainment (OR 1.33; 95% CI 1.03, 1.74); racial/ethnic minority status (OR 1.33; 95% CI 0.98, 1.80); rural residence (OR 1.56; 95% CI 1.26, 1.92); limited household income (OR 1.38; 95% CI 1.10, 1.73). Additionally adjusting for facility characteristics (added to the model individually and then simultaneously) did not substantially change these ORs suggesting that none of these characteristics explained the previously identified relationship between facilities serving vulnerable populations and false positive rates (Table 4).

While adjusting for facility characteristics did not substantially attenuate the association between vulnerability and false positive rates, the facility characteristic point estimates from these individual models suggested that availability of on-site ultrasound and biopsy services were associated with greater odds of a false positive (Table 5). Significant ORs ($p<0.05$) from these models ranged from 1.68 to 1.88 for on-site ultrasound and 1.24 to 1.30 for biopsy services. However, in the sensitivity analysis adjusting for all four facility characteristics simultaneously, these ORs were attenuated (ranged from 1.50 to 1.68 for on-site ultrasound and 1.10 to 1.23 for biopsy services, $p>0.05$ - data not shown), though estimated directions were consistent with primary models. Notably, the 10% of facilities without on-site ultrasound also lacked biopsy services. We detected no interaction (on the log-odds scale) between these services and vulnerability indices (p for interaction > 0.05), thus suggesting that facilities with these on-site diagnostic services tended to have higher false positive rates than those without these services, regardless of the vulnerability of the population served by these facilities.

## Discussion

Facilities serving vulnerable women had higher diagnostic mammography false positive rates than facilities serving primarily non-vulnerable women. These differences were not accounted for by differences in availability of on-site breast ultrasound or biopsy, academic medical affiliation, or profit status, even though the availability of on-site diagnostic services were associated with higher false positive rates.

Understanding the reasons driving differences in mammography interpretative performance is important to decrease breast cancer disparities and to curb unnecessary healthcare costs. Prior literature reports the excess costs from false positive screening mammography of $500 per mammogram(19). While specific estimates are not available for the fiscal impact of false positives in diagnostic mammography, likely false positive diagnostic mammography that lead to unnecessary biopsies are even more costly per abnormal reading, as these lead to excess biopsies, instead of follow-up mammography(17). As many facilities serving vulnerable women fund their mammography centers through foundation grants aimed at increasing access to screening for uninsured women(21, 22), false positives particularly can drain these limited resources.

Solutions to decreasing disparities in false positive rates start by identifying potential causes. Practice patterns of radiologists working at facilities that serve vulnerable women could account for our findings. Radiologists with more recent training (i.e. less experienced) and who read proportionately fewer diagnostic mammography tend to have higher false positive rates than other radiologists(18, 19), and such radiologists may more frequently practice at facilities serving vulnerable populations. Radiologists at these facilities may also recall patients more frequently due to recognition that often cancer prevalence and loss-to-follow-up rates are higher among women at these facilities(20). Interventions to recruit highly experienced, fellowship-trained radiologists may help improve diagnostic interpretive performance at these facilities(25).

Our finding that facilities with on-site diagnostic services have higher false positive rates is consistent with prior research demonstrating that readily available services may be more readily used(21). However, this finding may be driven by unmeasured characteristics associated with lack of such services at these facilities.

There are several limitations to this study. Income and rural residence was obtained using ZIP code averages, and insurance data was unavailable. We excluded mammography where breast density was unavailable. This study does not evaluate whether the follow-up rates for recalled mammograms differ by facility type. While our findings are consistent with previous work that suggests use of ultrasound increases false positive rates(22), the prevalence of ultrasound availability is extremely high in our sample, close to 90%. However, availability of ultrasound on-site may not be equated to use in individual women: the BCSC data is unable to consistently ascertain whether a woman actually received ultrasound in this cohort. Our dataset does not capture radiologist characteristics and prior training experience.

Neither on-site breast ultrasound or biopsy, academic medical center affiliation, nor profit status explain the higher diagnostic mammography false positive rates observed at facilities serving predominately vulnerable women. Interventions to improve the accuracy of diagnostic mammography interpretations should consider whether the higher false positives rates are driven by practice patterns of radiologists at these facilities. Recognizing that the availability of on-site diagnostic services may contribute to higher utilization of medical care overall, future studies should evaluate the appropriateness of referrals for biopsy in this context.

## Acknowledgments

This work was supported by the Agency for Health Care Research and Quality, Grant #1 K08 HS018090-01, NIH/NCRR/OD UCSF-CTSI Grant Number KL2 RR024130. California Breast Cancer Research Project, Grant #14IB-0062, and the National Cancer Institute-funded Breast Cancer Surveillance Consortium (U01CA63740, U01CA86076, U01CA86082, U01CA63736, U01CA70013, U01CA69976, U01CA63731, U01CA70040). Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the NIH. The collection of cancer data used in this study was supported in part by several state public health departments and cancer registries throughout the U.S. For a full description of these sources, please see: gn.http://breastscreening.cancer.gov/work/acknowledgement.html. The authors take full responsibility in the design of the study, the collection of the data, the analysis and interpretation of the data, the decision to submit the manuscript for publication, and the writing of the manuscript. We thank the participating women, mammography facilities, and radiologists for the data they have provided for this study. A list of the BCSC investigators and procedures for requesting BCSC data for research purposes are provided at: http://breastscreening.cancer.gov/.

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**Table 1**

Diagnostic mammogram-level characteristics, stratified by composite vulnerability score of the facility at which the mammogram was performed.

| | Composite vulnerability score[a] | | | | | |
|---|---|---|---|---|---|---|
| | Non-vulnerable (score = 0) | | Moderately vulnerable (score = 1 or 2) | | Highly vulnerable (score = 3 or 4) | |
| | N | % | N | % | N | % |
| *Total number of unique women served* | 41,231 | | 19,454 | | 8,476 | |
| *Total number of diagnostic mammograms* | 48,033 | | 21,195 | | 9,505 | |
| *Age group, years* | | | | | | |
| 40 – 49 | 21,273 | 44.3 | 9,164 | 43.2 | 3,762 | 39.6 |
| 50 – 59 | 14,513 | 30.2 | 6,321 | 29.8 | 2,754 | 29.0 |
| 60 – 69 | 7,348 | 15.3 | 3,530 | 16.7 | 1,841 | 19.4 |
| 70 – 80 | 4,899 | 10.2 | 2,180 | 10.3 | 1,148 | 12.1 |
| *Breast density* | | | | | | |
| 1: Almost entirely fat | 3,043 | 6.3 | 1,328 | 6.3 | 490 | 5.2 |
| 2: Scattered fibroglandular densities | 16,709 | 34.8 | 8,793 | 41.5 | 4,766 | 50.1 |
| 3: Heterogeneously dense | 22,635 | 47.1 | 8,726 | 41.2 | 3,370 | 35.5 |
| 4: Extremely dense | 5,646 | 11.8 | 2,348 | 11.1 | 879 | 9.3 |
| *Time since previous mammogram* | | | | | | |
| No previous mammogram | 2,948 | 6.1 | 1,814 | 8.6 | 1,010 | 10.6 |
| < 12 months | 15,897 | 33.1 | 7,540 | 35.6 | 2,597 | 27.3 |
| 12 - 18 months | 16,045 | 33.4 | 6,004 | 28.3 | 2,835 | 29.8 |
| 19 - 30 months | 7,002 | 14.6 | 2,891 | 13.6 | 1,411 | 14.8 |
| 31 - 42 months | 2,505 | 5.2 | 1,208 | 5.7 | 614 | 6.5 |
| 43+ months | 3,636 | 7.6 | 1,738 | 8.2 | 1,038 | 10.9 |
| *Mammography result* | | | | | | |
| Negative | 43,703 | 91.0 | 18,776 | 88.6 | 8,419 | 88.6 |
| Positive | 4,330 | 9.0 | 2,419 | 11.4 | 1,086 | 11.4 |

[a]Composite vulnerability scores were calculated by adding 1 for each of the following vulnerability indices met: *Education:* < 83% of the facility population completed high school; *Race/ethnicity:* > 30% of the facility population are minorities; *Rural/urban residence:* average percentage of rural residences among the facility population is > 52%; and *Income:* average median household income among the facility population is < $45,000.

**Table 2**

Facility characteristics by vulnerability index (facility population characteristics).

| | N | % with ultrasound services | % with biopsy services | % affiliated with academic medical center | % for profit[b] |
|---|---|---|---|---|---|
| ***Number of facilities*** | 139 | 89.9 | 61.2 | 10.1 | 32.3 |
| ***Education***[a] | | | | | |
| Non-vulnerable | 107 | 88.8 | 61.7 | 10.3 | 34.0 |
| Vulnerable | 32 | 93.8 | 59.4 | 9.4 | 25.9 |
| ***Race/ethnicity***[a] | | | | | |
| Non-vulnerable | 113 | 88.5 | 61.1 | 9.7 | 34.6 |
| Vulnerable | 26 | 96.2 | 61.5 | 11.5 | 21.7 |
| ***Rural/urban residence***[ac] | | | | | |
| Non-vulnerable | 92 | 89.1 | 56.5 | 13.0 | 45.0 |
| Vulnerable | 47 | 91.5 | 70.2 | 4.3 | 10.6 |
| ***Income***[ac] | | | | | |
| Non-vulnerable | 87 | 87.4 | 59.8 | 13.8 | 37.7 |
| Vulnerable | 52 | 94.2 | 63.5 | 3.9 | 24.0 |
| ***Composite vulnerability score***[d] | | | | | |
| 0 | 58 | 82.8 | 48.3 | 15.5 | 51.9 |
| 1 | 35 | 97.1 | 77.1 | 5.7 | 15.2 |
| 2 | 22 | 95.5 | 72.7 | 4.6 | 16.7 |
| 3 | 18 | 94.4 | 77.8 | 11.0 | 33.3 |
| 4 | 6 | 83.3 | 0.0 | 0.0 | 0.0 |

[a] Facilities serving vulnerable women include those serving: < 83% of the facility population completed high school; > 30% of the facility population are minorities; average percentage of rural residences among the facility population is > 52%; and average median household income among the facility population is < $45,000.

[b] % among facilities not missing ‘for profit’ status (12 facilities were missing this information)

[c] Rural residence and income are generated from area-level data

[d] Composite vulnerability scores were calculated by adding 1 for each of the vulnerability indices met.

**Table 3**

Sensitivity, False Positive Rates, Cancer Detection Rates (CDR) for diagnostic mammography by vulnerability index of the facility at which the mammogram was performed, unadjusted and adjusted for patient characteristics

| | N | Unadjusted sensitivity (%) | Adjusted sensitivity (%)[b] | Unadjusted false positive rate (%) | Adjusted false positive rate (%)[b] | Unadjusted CDR (per 1000 exams) | Adjusted CDR (per 1000 exams)[b] |
|---|---|---|---|---|---|---|---|
| *Number of facilities* | 139 | 84.2 | | 6.5 | | 37.2 | |
| ***Education[a]*** | | | | | | | |
| Non-vulnerable | 107 | 84.6 | 81.7 | 6.2 | 6.1 | 37.3 | 36.8 |
| Vulnerable | 32 | 82.5 | 79.4 | 8.0 | 7.9 | 36.9 | 39.3 |
| OR (95% CI) | | | 0.86 (0.61, 1.20) | | **1.33 (1.03, 1.74)** | | 1.07 (0.86, 1.34) |
| ***Race/ethnicity[a]*** | | | | | | | |
| Non-vulnerable | 113 | 84.5 | 81.2 | 6.3 | 6.2 | 37.1 | 35.9 |
| Vulnerable | 26 | 82.5 | 80.9 | 7.8 | 8.0 | 38.0 | 44.7 |
| OR (95% CI) | | | 0.98 (0.67, 1.44) | | 1.33 (0.98, 1.80) | | 1.26 (0.98, 1.62) |
| ***Rural/urban residence[ac]*** | | | | | | | |
| Non-vulnerable | 92 | 83.9 | 80.2 | 5.9 | 5.7 | 35.1 | 35.0 |
| Vulnerable | 47 | 85.0 | 83.2 | 8.4 | 8.5 | 44.0 | 42.9 |
| OR (95% CI) | | | 1.24 (0.91, 1.68) | | **1.56 (1.26, 1.92)** | | **1.24 (1.03, 1.50)** |
| ***Income[ac]*** | | | | | | | |
| Non-vulnerable | 87 | 84.7 | 81.3 | 6.3 | 5.9 | 36.4 | 35.5 |
| Vulnerable | 52 | 82.7 | 80.9 | 7.1 | 7.9 | 39.8 | 41.6 |
| OR (95% CI) | | | 0.97 (0.71, 1.33) | | **1.38 (1.10, 1.73)** | | 1.18 (0.98, 1.43) |
| ***Composite vulnerability score[d]*** | | | | | | | |
| | 58 | 84.8 | 81.0 | 5.7 | **5.3** | 35.5 | 33.8 |
| 1 | 35 | 83.7 | 81.9 | 7.7 | **6.8** | 39.8 | 37.8 |
| 2 | 22 | 83.9 | 81.4 | 7.9 | **7.3** | 39.9 | 41.7 |
| 3 | 18 | 81.8 | 79.0 | 7.7 | **8.4** | 39.0 | 42.1 |
| 4 | 6 | 88.5 | 88.0 | 8.6 | **10.6** | 48.5 | 46.2 |
| | | | p for trend = 0.34 | | **p for trend < 0.01** | | p for trend = 0.10 |

[a]Facilities serving vulnerable women include those serving: < 83% of the facility population completed high school; > 30% of the facility population are minorities; average percentage of rural residences among the facility population is > 52%; and average median household income among the facility population is < $45,000.

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[b] Adjusted for study site and patient characteristics: age, time since previous mammogram, and BI-RADS breast density

[c] Rural residence and income are generated from area-level data

[d] Composite vulnerability scores were calculated by adding 1 for each of the vulnerability indices met

## Table 4

False positive rates (%) for diagnostic mammography by vulnerability index of the facility at which the mammogram was performed, adjustment for patient and facility characteristics

| | N | Adjusted for Patient Characteristics[c] | Adjusted for Patient Characteristics[c] & Ultrasound Availability | Adjusted for Patient Characteristics[c] & Biopsy Availability | Adjusted for Patient Characteristics[c] & Affiliation with Academic Center | Adjusted for Patient Characteristics[c] & Profit Status[d] | Adjusted for Patient Characteristics[ce] & All Facility Characteristics |
|---|---|---|---|---|---|---|---|
| *Number of facilities* | 139 | | | | | | |
| ***Education***[a] | | | | | | | |
| Non-vulnerable | 107 | 6.1 | 6.1 | 6.0 | 6.0 | 5.7 | 5.7 |
| Vulnerable | 32 | 7.9 | 8.1 | 7.9 | 7.9 | 7.8 | 8.2 |
| OR (95% CI) | | **1.33 (1.03,1.74)** | **1.37 (1.05,1.77)** | **1.34 (1.04,1.47)** | **1.33 (1.03,1.74)** | **1.42 (1.06,1.89)** | **1.48 (1.11, 1.96)** |
| ***Race/ethnicity***[a] | | | | | | | |
| Non-vulnerable | 113 | 6.2 | 6.3 | 6.1 | 6.1 | 5.8 | 5.8 |
| Vulnerable | 26 | 8.0 | 8.0 | 8.2 | 8.0 | 7.8 | 8.2 |
| OR (95% CI) | | 1.33 (0.98,1.80) | 1.32(0.98,1.77) | **1.38 (1.02,1.86)** | 1.33 (0.98,1.80) | 1.39 (0.98, 1.96) | **1.46 (1.04, 2.05)** |
| ***Rural/urban residence***[ac] | | | | | | | |
| Non-vulnerable | 92 | 5.7 | 5.8 | 5.7 | 5.7 | 5.2 | 5.3 |
| Vulnerable | 47 | 8.5 | 8.5 | 8.4 | 8.6 | 7.6 | 7.8 |
| OR (95% CI) | | **1.56 (1.26,1.92)** | **1.54 (1.25,1.89)** | **1.51 (1.22,1.87)** | **1.57 (1.27,1.94)** | **1.50 (1.20,1.87)** | **1.51 (1.21, 1.90)** |
| ***Income***[ac] | | | | | | | |
| Non-vulnerable | 87 | 5.9 | 6.0 | 5.9 | 5.9 | 5.5 | 5.6 |
| Vulnerable | 52 | 7.9 | 8.0 | 7.8 | 7.9 | 7.0 | 7.1 |
| OR (95% CI) | | **1.38 (1.10,1.73)** | **1.37 (1.10,1.71)** | **1.36 (1.09,1.70)** | **1.38 (1.10,1.73)** | **1.29 (1.02,1.63)** | **1.29 (1.03, 1.63)** |
| ***Composite vulnerability score***[e] | | | | | | | |
| 0 | 58 | **5.3** | **5.4** | **5.4** | **5.3** | **4.8** | **5.0** |
| 1 | 35 | **6.8** | **6.7** | **6.6** | **6.9** | **6.2** | **6.2** |
| 2 | 22 | **7.3** | **7.3** | **7.2** | **7.4** | **7.1** | **7.3** |
| 3 | 18 | **8.4** | **8.7** | **8.1** | **8.4** | **7.9** | **8.1** |
| 4 | 6 | **10.6** | **10.6** | **11.4** | **10.6** | **9.4** | **10.4** |
| | | **p for trend < 0.01** | **p for trend < 0.01** | **p for trend < 0.01** | **p for trend < 0.01** | **p for trend < 0.01** | **p for trend < 0.01** |

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[a]Facilities serving vulnerable women include those serving: < 83% of the facility population completed high school; > 30% of the facility population are minorities; average percentage of rural residences among the facility population is > 52%; and average median household income among the facility population is < $45,000.

[b]Rural residence and income are generated from area-level data

[c]Adjusted for study site and patient characteristics: age, time since previous mammogram, and BI-RADS breast density

[d]Composite vulnerability scores were calculated by adding 1 for each of the vulnerability indices met.

[e]Models with profit status had N = 127 facilities as profit status was not collected from 1 site.

## Table 5

Association of facility characteristics and false positive rates, based on models adjusted for patient characteristics and individual vulnerability measure in Table 4

| Facility characteristic[b] | Model with Education OR (95% CI)[a] | Model with Race/ethnicity OR (95% CI)[a] | Model with Rural/urban OR (95% CI)[ab] | Model with Income OR (95% CI)[ab] | Model with Composite score OR (95% CI) |
|---|---|---|---|---|---|
| | | | Odds of a False-Positive | | |
| *Ultrasound service*[c] | **1.88 (1.14, 3.10)** | **1.78 (1.08, 2.94)** | **1.68 (1.03, 2.74)** | **1.76 (1.07, 2.90)** | **1.73 (1.06, 2.83)** |
| *Biopsy Service*[d] | **1.28 (1.02, 1.59)** | **1.30 (1.04, 1.62)** | 1.17 (0.94, 1.45) | **1.24 (1.00, 1.55)** | **1.25 (1.00, 1.56)** |
| *Affiliation with an Academic Center*[e] | 0.97 (0.71, 1.32) | 0.97 (0.71, 1.32) | 1.07 (0.80, 1.43) | 0.99 (0.73, 1.35) | 1.03 (0.77, 1.38) |
| *For Profit*[fg] | 0.81 (0.65, 1.02) | 0.81 (0.64, 1.02) | 0.88 (0.70, 1.10) | 0.82 (0.65, 1.04) | 0.93 (0.74, 1.17) |

[a]Adjusted for study site and patient characteristics: age, time since previous mammogram, and BI-RADS breast density

[b]Rural/urban residence and income are generated from area-level data

[c]‘No ultrasound services’ is the referent group

[d]‘No biopsy services’ is the referent group

[e]‘No academic affiliation’ is the referent group

[f]‘Not for profit’ is the referent group

[g]N = 127, as one site (N = 12) did not report profit status