Title

Availability of Advanced Breast Imaging at Screening Facilities Serving Vulnerable Populations

Journal

Journal of Medical Screening, 23(1)

ISSN

0969-1413

Authors

Lee, Christoph I
Bogart, Andy
Germino, Jessica C
et al.

Publication Date

2016-03-01

DOI

10.1177/0969141315591616

Peer reviewed

HHS Public Access

Author manuscript

J Med Screen. Author manuscript; available in PMC 2017 March 01.

Published in final edited form as:

J Med Screen. 2016 March ; 23(1): 24–30. doi:10.1177/0969141315591616.

Availability of Advanced Breast Imaging at Screening Facilities Serving Vulnerable Populations

Christoph I. Lee, MD, MSHS[1,2], **Andy Bogart, MS**[3], **Jessica C. Germino, MD**[1], **L. Elizabeth Goldman, MD, MCR**[4], **Rebecca A. Hubbard, PhD**[5], **Jennifer S. Haas, MD, MSPH**[6], **Deirdre A. Hill, PhD**[7], **Anna N.A. Tosteson, ScD**[8], **Jennifer A. Alford-Teaster, MA, MPH**[8], **Wendy B. DeMartini, MD**[9], **Constance D. Lehman, MD, PhD**[1], and **Tracy L. Onega, PhD**[8]

[1]Department of Radiology, University of Washington School of Medicine; 825 Eastlake Avenue East, Seattle, WA 98109

[2]Department of Health Services, University of Washington School of Public Health; 825 Eastlake Avenue East, Seattle, WA 98109

[3]Group Health Research Institute; 1730 Minor Avenue #1600, Seattle, WA, 98101

[4]Department of Internal Medicine, University of California, San Francisco School of Medicine; 1001 Potrero Ave, Box 1364, San Francisco, CA 94110

[5]Department of Biostatistics & Epidemiology, Perelman School of Medicine, University of Pennsylvania; 423 Guardian Drive, Philadelphia, PA 19104

[6]Division of General Internal Medicine and Primary Care, Brigham and Women's Hospital; Department of Medicine, Harvard Medical School; Dana Farber Harvard Cancer Institute; Department of Social and Behavioral Sciences, Harvard School of Public Health; 1620 Tremont Street, Boston, MA 02120

[7]Department of Internal Medicine, Cancer Research and Treatment Center, University of New Mexico; 1201 Camino de Salud NE, 1 University of New Mexico, Albuquerque, NM, 87102

[8]Departments of Medicine and Community & Family Medicine, Dartmouth Institute for Health Policy & Clinical Practice, Norris Cotton Cancer Center, Geisel School of Medicine; One Medical Center Drive, Lebanon, NH 03756

Corresponding Author Contact Information (also contact for reprints): Christoph I. Lee, MD, MSHS, Assistant Professor, Radiology; Adjunct Assistant Professor, Health Services, University of Washington, Schools of Medicine and Public Health, 825 Eastlake Avenue East, G3-200, Seattle, WA 98109-1023, stophlee@uw.edu, Phone: (206) 288-6783, Fax: (206) 288-6473.
Co-Authors' Contact Information:
Andy Bogart, MS: abogart@rand.org
Jessica C. Germino, MD: germinoj@u.washington.edu
L. Elizabeth Goldman, MD, MCR: LeGoldman@medsfgh.ucsf.edu
Rebecca A. Hubbard, PhD: rhubb@mail.med.upenn.edu
Jennifer S. Haas, MD, MSPH: JHAAS@partners.org
Deirdre A. Hill, PhD: dahill@salud.unm.edu
Anna N.A. Tosteson, ScD: Anna.N.A.Tosteson@dartmouth.edu
Jennifer A. Alford-Teaster, MA, MPH: Jennifer.A.Alford-Teaster@dartmouth.edu
Wendy B. DeMartini, MD: WDeMartini@uwhealth.org
Constance D. Lehman, MD, PhD: clehman@seattlecca.org
Tracy L. Onega, PhD: Tracy.L.Onega@dartmouth.edu

[9]Department of Radiology, University of Wisconsin School of Medicine and Public Health; 600 Highland Avenue, Madison WI 53792

Abstract

Objective—Among vulnerable women, unequal access to advanced breast imaging modalities beyond screening mammography may lead to delays in cancer diagnosis and unfavorable outcomes. We aimed to compare on-site availability of advanced breast imaging services (ultrasound (US), magnetic resonance imaging (MRI), and image-guided biopsy) between imaging facilities serving vulnerable patient populations and those serving non-vulnerable populations.

Setting—73 United States imaging facilities across five Breast Cancer Surveillance Consortium regional registries during calendar years 2011–2012.

Methods—We examined facility and patient characteristics across a large, national sample of imaging facilities and patients served. We characterized facilities as serving vulnerable populations based on the proportion of mammograms performed on women with lower educational attainment, lower median income, racial/ethnic minority status, and rural residence. We performed multivariable logistic regression to determine relative risks of on-site availability of advanced imaging at facilities serving vulnerable women versus facilities serving non-vulnerable women.

Results—Facilities serving vulnerable populations were as likely (RR for MRI = 0.71 [95% CI 0.42, 1.19]; RR for MRI-guided biopsy = 1.07 [0.61, 1.90]; RR for stereotactic biopsy = 1.18 [0.75, 1.85]) or more likely (RR for US = 1.38 [95% CI 1.09, 1.74]; RR for US-guided biopsy = 1.67 [1.30, 2.14]) to offer advanced breast imaging services as those serving non-vulnerable populations.

Conclusions—Advanced breast imaging services are physically available on-site for vulnerable women in the United States, but it is unknown whether factors such as insurance coverage or out-of-pocket costs might limit their use.

Keywords

breast cancer; screening mammography; disparities; access; advanced breast imaging

INTRODUCTION

For many areas of health care, whether patients have access to and utilize specific medical technologies is often influenced by local availability of resources (1–3). However, on-site availability of healthcare resources, which likely plays a role in downstream utilization, remains relatively unexplored for cancer care (4). With regards to breast cancer screening and diagnosis, it is uncertain whether differences in the ready availability of imaging resources beyond mammography contribute to persistent disparities in breast cancer outcomes (5). Prior studies addressing timeliness of follow-up after abnormal mammography have been limited by a lack of data regarding the physical availability of advanced breast imaging modalities (6, 7).

Diagnostic work-up after abnormal screening mammography often requires the use of breast ultrasound (US), imaging-guided core breast biopsy (e.g., US-guided breast biopsy, stereotactic breast biopsy), and potentially breast magnetic resonance imaging (MRI) (e.g., extent of disease work-up prior to surgery) (8). Women at higher risk of developing breast cancer also seek supplemental screening modalities, including screening breast US and screening breast MRI (9). The demand for advanced breast imaging is likely to increase with new breast density reporting legislation requiring imaging facilities to directly inform women with mammographically dense breasts that they are at increased risk of developing cancer and should discuss potential supplemental screening with their physicians (10).

Unfortunately, recent analyses have shown both disadvantages in geographic access to and utilization of advanced breast imaging technologies among vulnerable women (11, 12). These women – including those from racial/ethnic minority backgrounds, with lower educational attainment, lower income, and those living in rural settings – continue to bear a disproportionate burden of breast cancer mortality (13–17). For instance, African-American women had a mortality rate of 49 per 100,000 in 2006, compared to 35 per 100,000 for Caucasian women, even though African-American women have lower breast cancer incidence than Caucasian women. Moreover, since 1990, breast cancer mortality rates have decreased an average 2.4% per year for Caucasian women, but only 1.1% per year for African-American women (18). Vulnerable women also experience lower rates of screening as well as longer wait times for diagnostic evaluation after abnormal screening, and more advanced cancer stage at diagnosis compared to non-vulnerable women (19). However, it remains uncertain whether or not these persistent disparities are associated with the physical availability of advanced breast imaging at imaging facilities attended by vulnerable women versus non-vulnerable women.

Therefore, our objective was to compare the on-site availability of advanced breast imaging capabilities (including breast US, breast MRI, and imaging-guided biopsy procedures) between screening mammography imaging facilities serving vulnerable populations and those serving non-vulnerable populations. We examined data from a large, national sample of screening mammography facilities in the Breast Cancer Surveillance Consortium (BCSC) and hypothesized that facilities serving more vulnerable women were less likely to have on-site availability of advanced breast imaging and imaging-guided biopsy services, potentially contributing to disparities in patient outcomes among vulnerable populations.

METHODS

Study Participants

The National Cancer Institute-funded BCSC consists of pooled breast imaging registry data shown to be representative of U.S. women undergoing routine screening mammography with regards to age, ethnicity, and urban or rural residence (20). We analyzed data from five regional registries pooled at the BCSC Statistical Coordinating Center (SCC) for calendar years 2011 and 2012 (North Carolina, San Francisco, Vermont, Chicago, and Western Washington). The SCC and each registry received institutional review board approval for either active or passive consenting processes or a waiver of consent to enroll individual facilities, link data, and perform analytic studies. All procedures were Health Insurance

Portability and Accountability Act (HIPAA) compliant, and the SCC and each registry received federal certificates of confidentiality and other protections for the identities of individual community facilities.

Facility Characteristics

Each of the five registries obtained data from their respective imaging facilities that offer screening mammography. Advanced breast imaging data for each individual facility included the availability of breast US, breast MRI, stereotactic core breast biopsy, US-guided core breast biopsy, and MRI-guided core breast biopsy. Facilities also reported data regarding their academic affiliation (if any), for-profit versus not-for-profit status, facility location (hospital, stand-alone office, or other), and practice type. For practice type, we categorized each facility as one of the following: a non-radiology practice, breast imaging only practice, full diagnostic radiology practice, or a multi-specialty breast center. We defined a non-radiology practice as a facility located within and operated by a different specialty (e.g., obstetrics and gynecology clinic). We defined a breast imaging only practice as a facility that only offers imaging services specific to the breasts and no other body part. We defined a full diagnostic radiology practice as one that offers imaging services for multiple body parts. Finally, we considered a multi-specialty breast center to be part of an integrated care center with on-site specialists in addition to radiologists (e.g., a cancer center with on-site breast oncologists).

Vulnerability Indices

To determine whether BCSC facilities served vulnerable or non-vulnerable populations, we used methods and definitions employed in our prior studies (21–24). Briefly, we defined vulnerability based on four sociodemographic characteristics: race/ethnicity, educational attainment, household income, and rural or urban residence. We recorded these characteristics at each mammography exam conducted at each BCSC facility in calendar years 2011 and 2012. For women's race/ethnicity, we used self-reported information provided at the time of mammography. For income, education level, and rural place of residence, we used geocoded linkages between residential zip codes and 2010 Census block-level data to assign each woman a median household income, education level, and a rural/urban score.

To characterize vulnerability of the patient population served by each facility, we calculated the following continuous facility-level vulnerability indices based on aggregated individual woman-level vulnerability measures across all mammography examinations performed at each facility in 2011–2012: 1) percentage of population composed of minorities (African-American or Hispanic/Pacific-Islander/Hawaiian/Native American race/ethnicity), 2) percentage of population with ≤ high school-level education, 3) average median household income, and 4) average percentage of rural residence. We then dichotomized continuous vulnerability indices to provide binary facility-level vulnerability classifications for patient populations served by each facility. The following cut-off values were determined by taking one standard deviation above or below the means of the continuous measures: 1) racial/ethnic minority percentage > 34.5%, 2) > 15.8% of exams among women with less than high school education, 3) average median income < $52,517, and 4) average percentage of rural

residences > 68.1%. In our multivariable analysis, we considered a facility to serve a vulnerable population if the threshold for any one of these four composite indices was met. We considered facilities not meeting any of the four thresholds as serving non-vulnerable patient populations.

Analysis

We performed all statistical analyses using SAS version 9.3 (SAS Institute, Cary, NC). We first computed descriptive statistics for facility-level characteristics, on-site availability of advanced breast imaging services, availability of advanced imaging services based on facility-level characteristics, and availability of advanced imaging services based on vulnerability indices. We then used unadjusted log binomial generalized estimating equations (GEE) models to calculate the relative risk of facilities serving vulnerable populations having on-site availability of different advanced breast imaging services, allowing for correlation among facilities belonging to the same group practice. Specifically, we examined the relative risk of facilities having on-site breast US, breast MRI, US-guided breast biopsy, stereotactic breast biopsy, and MRI-guided breast biopsy services based on vulnerability of patient population served (for each vulnerability characteristic and overall). We also estimated adjusted log binomial GEE models for each facility vulnerability characteristic adjusting for whether or not the facility was located in an urban core based on Rural Urban Commuting Area Codes derived from U.S. Census commuting data (except for the patient rural residence index due to high collinearity between facility rurality and rurality of patients served). These additional adjusted models examined whether the relative risks of imaging availability by vulnerability index changed after accounting for the physical setting of imaging facilities.

Each model regressed a binary indicator of advanced imaging service provision on dummy variables for the patient population vulnerability characteristic of interest. Our GEE models accounted for correlation among individual facilities belonging to the same imaging group practice (one of 34 group practices) through the use of the robust Huber-White (sandwich) variance estimator. We estimated 95% confidence bounds around each probability estimate via the delta method.

RESULTS

Facility Characteristics and Availability of Advanced Imaging

In total, we obtained data from 73 imaging facilities and 799,467 mammograms performed across five Breast Cancer Surveillance Consortium regional registries during calendar years 2011–2012. We report imaging facility-level characteristics in Table 1. The majority of facilities included in our analysis were not-for-profit (77%), hospital-based (64%), full diagnostic radiology practices (55%), and not academically affiliated (92%). Breast US was available on-site at 75% and breast MRI was available on-site at 42% of facilities. Stereotactic biopsy was available on-site at 39%, US-guided biopsy at 57%, and MRI-guided biopsy at 29% of facilities.

We describe the on-site availability of advanced breast imaging and image-guided biopsy services based on facility-level characteristics in Table 2. In general, availability of breast US, breast MRI, and image-guided biopsy services were variable, but largely not dependent upon a facility's for-profit status, academic status, or facility location. Breast US, breast MRI, and image-guided biopsy services were most likely available on-site at multi-specialty breast centers.

Facilities Serving Vulnerable Populations and Availability of Advanced Imaging

Among all imaging facilities, 47% (34/73) were categorized as serving a vulnerable patient population (meeting the threshold value for at least one of the four vulnerability characteristics). We describe the availability of advanced breast imaging and image-guided biopsy services based on each of the vulnerability indices in Table 3 and detail the multivariable analyses of on-site advanced imaging availability and associations with the vulnerability of the patient populations served in Table 4.

Unadjusted regression analyses identified no significant differences in on-site availability of breast MRI (RR = 0.71 [95% CI 0.42, 1.19]), MRI-guided biopsy (RR = 1.07 [0.61, 1.90]), and stereotactic biopsy (RR = 1.18 [0.75, 1.85]) at facilities serving vulnerable populations versus facilities serving non-vulnerable populations. However, facilities serving vulnerable populations were statistically more likely to provide on-site breast US (RR = 1.38 [95% CI 1.09, 1.74]) and US-guided biopsy (RR = 1.67 [1.30, 2.14]) services than facilities serving non-vulnerable populations. We also found a borderline statistically significant relationship between rural population served and lower on-site availability of breast MRI (RR = 0.33 [0.11, 1.00]).

Results from our adjusted models accounting for whether or not imaging facilities were located in an urban core are detailed in Table 5. Interestingly, after adjusting for the urban versus rural setting of facilities themselves, those serving a larger proportion of racial/ethnic minority patients were significantly more likely to offer US-guided and MRI-guided imaging-guided biopsy services (RR = 1.40 [1.09, 1.81] and RR = 2.24 [1.06, 4.75], respectively), and borderline significantly more likely to offer stereotactic core biopsy (RR = 1.67 [1.00, 2.78]).

DISCUSSION

Contrary to our original hypothesis, we found that imaging facilities serving more vulnerable women were as or more likely to have on-site availability of advanced breast imaging modalities and imaging-guided biopsy services. We controlled for differences in facility profit status, academic affiliation, practice type, and practice setting. Our findings suggest that physical on-site availability does not contribute to observed health disparities among vulnerable populations with regards to accessing advanced breast imaging services, addressing a critical knowledge gap regarding the relationship between health care resource availability and disparities in breast cancer care.

Interestingly, facilities serving vulnerable populations were more likely to offer breast US and US-guided breast biopsy services on-site than facilities serving non-vulnerable

populations. The reasons for these seemingly paradoxical findings are unclear. Potential factors may include rural versus urban practice settings and the lack of availability of additional diagnostic imaging centers in close proximity of rural screening facilities. Since breast US and US-guided breast biopsies represent the two most common advanced imaging services utilized in the diagnostic setting after abnormal mammography, it is not unreasonable for facilities to offer these additional services if they represent the only breast imaging facility accessible to a large patient population.

Of the four vulnerability indices, education level of the population served was not associated with more or less on-site availability of advanced breast imaging services. Race/ethnicity, income, and rural versus non-rural residence of the patient populations served all contributed to differences in advanced imaging availability at the facility-level. The significant relationship between rural population served and lower on-site availability of breast MRI corroborates an earlier analysis by our group regarding geographic access to breast imaging in the U.S. that found longer travel times for rural residents with regards to obtaining breast MRI (11).

Our findings should not be misinterpreted to suggest that there are no disparities with regards to access and utilization of breast imaging technologies beyond screening mammography among vulnerable women. Rather, our analysis is limited in scope to the physical on-site availability of additional imaging modalities at the facility level among a large, national sample of facilities, and accounts for the possibility of facilities being part of the same group practice. While our study results suggest that physical on-site availability does not contribute to potential disparities in access to advanced breast imaging technologies between vulnerable and non-vulnerable women, other enabling factors such as patient insurance status and additional out-of-pocket expenses are not addressed due to lack of data and were considered outside the scope of this analysis. Moreover, our study is limited to addressing facility-level availability of breast ultrasound, breast MRI, and image-guided biopsy services among differing patient populations, and does not address newer technologies such as digital breast tomosynthesis. This technology, approved by the FDA in 2011 and currently being adopted in community settings at a rapid pace (25), was available in only 6% (4/71) of BCSC facilities at the time of our study.

In conclusion, our study suggests that on-site availability of advanced breast imaging and image-guided biopsy services do not significantly differ between facilities serving vulnerable women and those serving non-vulnerable women. However, future research should address potential disparities in actual on-site utilization of advanced breast imaging modalities and image-guided biopsy services among vulnerable women, including examination of additional patient characteristics such as insurance status and health literacy. Our group’s prior research suggests that vulnerable women experience longer wait times for follow-up of abnormal mammogram at facilities serving vulnerable populations (22). Thus, while we found that advanced imaging services may be physically available on-site at imaging facilities, these technologies may go under-utilized by vulnerable women due to other enabling factors.

ACKNOWLEDGEMENTS

We thank the participating mammography facilities, patients, and radiologists of the BCSC for the data they 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/.

FUNDING SOURCES

This work was supported by grants from the†National Cancer Institute (RC2CA148577 and, for the Breast Cancer Surveillance Consortium (BCSC), P01CA154292 and HHSN261201100031C), as well by a grant from the American Cancer Society (MRSG-14-160-01-CPHPS).

REFERENCES

1. Birkmeyer JD, Sharp SM, Finlayson SR, et al. Variation profiles of common surgical procedures. Surgery. 1998; 124:917–923. [PubMed: 9823407]
2. Every NR, Larson EB, Litwin PE, et al. The association between on-site cardiac catheterization facilities and the use of coronary angiography after acute myocardial infarction. Myocardial Infarction Triage and Intervention Project Investigators. N Engl J Med. 1993; 329:546–551. [PubMed: 8336755]
3. Wennberg D, Dickens J Jr, Soule D, et al. The relationship between the supply of cardiac catheterization laboratories, cardiologists and the use of invasive cardiac procedures in northern New England. J Health Serv Res Policy. 1997; 2:75–80. [PubMed: 10180368]
4. Wong SL, Wei Y, Birkmeyer JD. Use of adjuvant radiotherapy at hospitals with and without on-site radiation services. Cancer. 2007; 109:796–801. [PubMed: 17211840]
5. Ademuyiwa FO, Edge SB, Erwin DO, et al. Breast cancer racial disparities: unanswered questions. Cancer Res. 2011; 71:640–644. [PubMed: 21135114]
6. Rosenberg RD, Haneuse SJ, Geller BM, et al. Timeliness of follow-up after abnormal screening mammogram: variability of facilities. Radiology. 2011; 261:404–413. [PubMed: 21900620]
7. Yabroff KR, Ashbeck E, Rosenberg R. Trends in time to completion of mammographic screening and follow-up services. AJR Am J Roentgenol. 2007; 188:242–245. [PubMed: 17179373]
8. Hooley RJ, Andrejeva L, Scoutt LM. Breast cancer screening and problem solving using mammography, ultrasound, and magnetic resonance imaging. Ultrasound Q. 2011; 27:23–47. [PubMed: 21343800]
9. Sickles EA. The use of breast imaging to screen women at high risk for cancer. Radiol Clin North Am. 2010; 48:859–878. [PubMed: 20868890]
10. Lee CI, Bassett LW, Lehman CD. Breast density legislation and opportunities for patient-centered outcomes research. Radiology. 2012; 264:632–636. [PubMed: 22919037]
11. Onega T, Hubbard R, Hill D, et al. Geographic access to breast imaging for US women. J Am Coll Radiol. 2014; 11:874–882. [PubMed: 24889479]
12. Wernli KJ, Demartini WB, Ichikawa L, et al. Patterns of breast magnetic resonance imaging use in community practice. JAMA Intern Med. 2014; 174:125–132. [PubMed: 24247555]
13. Chlebowski RT, Chen Z, Anderson GL, et al. Ethnicity and breast cancer: factors influencing differences in incidence and outcome. J Natl Cancer Inst. 2005; 97:439–448. [PubMed: 15770008]
14. Elmore JG, Nakano CY, Linden HM, et al. Racial inequities in the timing of breast cancer detection, diagnosis, and initiation of treatment. Med Care. 2005; 43:141–148. [PubMed: 15655427]
15. Williams DL, Tortu S, Thomson J. Factors associated with delays to diagnosis and treatment of breast cancer in women in a Louisiana urban safety net hospital. Women Health. 2010; 50:705–718. [PubMed: 21170814]
16. Tian N, Goovaerts P, Zhan FB, et al. Identifying risk factors for disparities in breast cancer mortality among African-American and Hispanic women. Women's Health Issues. 2012; 22:e267–e276. [PubMed: 22265181]

17. Ayanian JZ, Kohler BA, Abe T, et al. The relation between health insurance coverage and clinical outcomes among women with breast cancer. N Engl J Med. 1993; 329:326–331. [PubMed: 8321261]
18. Smigal C, Jemal A, Ward E, et al. Trends in breast cancer by race and ethnicity: update 2006. CA Cancer J Clin. 2006; 56:168–183. [PubMed: 16737949]
19. Richards MA, Westcombe AM, Love SB, et al. Influence of delay on survival in patients with breast cancer: a systematic review. Lancet. 1999; 353:1119–1126. [PubMed: 10209974]
20. Ballard-Barbash R, Taplin SH, Yankaskas BC, et al. Breast Cancer Surveillance Consortium: a national mammography screening and outcomes database. AJR Am J Roentgenol. 1997; 169:1001–1008. [PubMed: 9308451]
21. Goldman LE, Haneuse SJ, Miglioretti DL, et al. An assessment of the quality of mammography care at facilities treating medically vulnerable populations. Med Care. 2008; 46:701–708. [PubMed: 18580389]
22. Goldman LE, Walker R, Hubbard R, et al. Timeliness of abnormal screening and diagnostic mammography follow-up at facilities serving vulnerable women. Med Care. 2013; 51:307–314. [PubMed: 23358386]
23. Goldman LE, Walker R, Miglioretti DL, et al. Facility characteristics do not explain higher false-positive rates in diagnostic mammography at facilities serving vulnerable women. Med Care. 2012; 50:210–216. [PubMed: 22186768]
24. Goldman LE, Walker R, Miglioretti DL, et al. Accuracy of diagnostic mammography at facilities serving vulnerable women. Med Care. 2011; 49:67–75. [PubMed: 20966780]
25. Friedewald SM, Rafferty EA, Rose SL, et al. Breast cancer screening using tomosynthesis in combination with digital mammography. JAMA. 2014; 311:2499–2507. [PubMed: 25058084]

Table 1

Facility Characteristics

Facility Characteristic	Total n = 73
Profit Status (n=56; 17 unknown*)	
For profit	13 (23.2%)
Not for profit	43 (76.8%)
Academic Status (n=73)	
Yes (with or without fellowship program)	6 (8.2%)
No	67 (91.8%)
Radiology Practice Type (n=73)	
Multi-specialty breast center	21 (28.8%)
Full diagnostic radiology practice	40 (54.8%)
Radiology practice limited to breast imaging only	5 (6.8%)
Non-radiology practice	7 (9.6%)
Facility Location (n=73)	
Hospital	47 (64.4%)
Office (stand-alone)	17 (23.3%)
Other	9 (12.3%)
MRI services (n=71; 2 unknown)	
None	41 (57.7%)
Screening and diagnostic	19 (26.8%)
Screening only	1 (1.4%)
Diagnostic only	10 (14.1%)
Ultrasound services (n=73)	
None	18 (24.7%)
Screening and diagnostic	20 (27.4%)
Diagnostic only	35 (47.9%)
Ultrasound guided biopsy services (n=72; 1 unknown)	
No	31 (43.1%)
Yes	41 (56.9%)
Magnetic resonance guided biopsy services (n=72; 1 unknown)	
No	51 (70.8%)
Yes	21 (29.2%)
Stereotactic guided biopsy services (n=72; 1 unknown)	
No	44 (61.1%)
Yes	28 (38.9%)
Facility Vulnerability Indices (n=73)	
Education (Based on 2010 Census data)	
Not Vulnerable	57 (78.1%)
Vulnerable	16 (21.9%)
Race/ethnicity (Based on exam-level information)	
Not Vulnerable	60 (82.2%)

Facility Characteristic	Total n = 73
Vulnerable	13 (17.8%)
Rurality (Based on 2010 Census data)	
Not Vulnerable	53 (72.6%)
Vulnerable	20 (27.4%)
Median Income (Based on 2010 Census data)	
Not Vulnerable	52 (71.2%)
Vulnerable	21 (28.8%)
At Least One of the Indices Above	
Not Vulnerable	39 (53.4%)
Vulnerable	34 (46.6%)

* One BCSC registry does not report profit status in order to protect the anonymity of its facilities

Table 2

Advanced Breast Imaging and Image-Guided Biopsy Availability by Facility Characteristic

Facility Characteristics	Ultrasound	MRI	Ultrasound Guided Biopsy	MR Guided Biopsy	Stereotactic Guided Biopsy
Profit Status*					
For profit (n=13)	10 (76.9%)	4 (30.8%)	3 (25%)	1 (8.3%)	2 (16.7%)
Not for profit (n=43)	32 (74.4%)	19 (46.3%)	26 (60.5%)	15 (34.9%)	19 (44.2%)
Academic Medical Center Status					
Yes (n=6)	4 (66.7%)	4 (66.7%)	4 (66.7%)	4 (66.7%)	4 (66.7%)
No (n=67)	51 (76.1%)	26 (40%)	37 (56.1%)	17 (25.8%)	24 (36.4%)
Radiology Practice Type					
Multi-specialty breast center (n=21)	21 (100%)	17 (81%)	20 (95.2%)	15 (71.4%)	18 (85.7%)
Full diagnostic radiology practice (n=40)	30 (75%)	13 (34.2%)	21 (53.8%)	6 (15.4%)	10 (25.6%)
Radiology practice limited to breast imaging only (n=5)	3 (60%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Non-radiology practice (n=7)	1 (14.3%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Facility Location					
Hospital or located with hospital (n=47)	38 (80.9%)	24 (53.3%)	35 (74.5%)	19 (40.4%)	25 (53.2%)
Office, not located with hospital (n=17)	8 (47.1%)	3 (17.6%)	2 (12.5%)	1 (6.3%)	1 (6.3%)
Other (n=9)	9 (100%)	3 (33.3%)	4 (44.4%)	1 (11.1%)	2 (22.2%)

*One BCSC registry does not report profit status in order to protect the anonymity of its facilities.

Percentages shown are calculated in rows for each modality. Facilities missing imaging availability information: 2 unknown for MRI and 1 unknown for all modalities of guided biopsy. The availability of ultrasound, MRI, and each modality of guided biopsy differed significantly ($p < 0.05$) by radiology practice type, and by facility location. Additionally, the availability of MR guided biopsy was significantly higher at academic medical centers than at non-academic facilities ($p=0.045$). All statistical tests account for clustering within practice.

Table 3

Advanced Breast Imaging and Image-Guided Biopsy Availability by Vulnerable Indices

Facility Vulnerability Indicators	Ultrasound	MRI	Ultrasound Guided Biopsy	MR Guided Biopsy	Stereotactic Guided Biopsy
Education: at least 15.8% of adults educated below high school graduation (census)					
Vulnerable	12 (75%)	6 (37.5%)	10 (62.5%)	6 (37.5%)	6 (37.5%)
Not Vulnerable	43 (75.4%)	24 (43.6%)	31 (55.4%)	15 (26.8%)	22 (39.3%)
Race/ethnicity: at least 34.5% self-reporting minority status					
Vulnerable	10 (76.9%)	7 (53.8%)	9 (69.2%)	7 (53.8%)	7 (53.8%)
Not Vulnerable	45 (75%)	23 (39.7%)	32 (54.2%)	14 (23.7%)	21 (35.6%)
Rurality: at least 68.1% rural residents					
Vulnerable	19 (95%)	3 (15%)	14 (70%)	3 (15%)	7 (35%)
Not Vulnerable	36 (67.9%)	27 (50.9%)	27 (50.9%)	18 (34%)	21 (39.6%)
Income: Average median income below $52,517					
Vulnerable	19 (90.5%)	6 (28.6%)	14 (66.7%)	5 (23.8%)	8 (38.1%)
Not Vulnerable	36 (69.2%)	24 (46.2%)	27 (51.9%)	16 (30.8%)	20 (38.5%)
At least one vulnerability indicator					
Vulnerable	30 (88.2%)	11 (32.4%)	24 (70.6%)	10 (29.4%)	14 (41.2%)
Not Vulnerable	25 (64.1%)	19 (48.7%)	17 (43.6%)	11 (28.2%)	14 (35.9%)

Note: Facilities missing imaging availability information: 2 for MRI, 1 for all modalities of guided biopsy. Percentages shown are calculated in rows for each modality.

Table 4

Unadjusted Multivariable Models for Imaging Availability Associated with Facility Vulnerability Indices

Facility Vulnerability Indices	Ultrasound RR (95% CI)	MRI RR (95% CI)	Ultrasound Guided Biopsy RR (95% CI)	MR Guided Biopsy RR (95% CI)	Stereotactic Guided Biopsy RR (95% CI)
Education: at least 15.8% of adults educated below high school graduation	0.99 (0.75, 1.33)	0.86 (0.49, 1.50)	1.13 (0.82, 1.54)	1.40 (0.77, 2.53)	0.95 (0.55, 1.64)
Race/ethnicity: at least 34.5% self-reporting minority status	1.03 (0.82, 1.28)	1.36 (0.70, 2.62)	1.28 (0.88, 1.85)	2.27 (1.19, 4.32)	1.51 (0.99, 2.32)
Rurality: at least 68.1% rural residents	1.40 (1.07, 1.82)	0.33 (0.11, 1.00)	1.45 (0.93, 2.25)	0.46 (0.15, 1.46)	0.93 (0.47, 1.86)
Income: Average census-based median income below $52,517	1.31 (1.06, 1.60)	0.68 (0.37, 1.27)	1.35 (0.94, 1.94)	0.81 (0.39, 1.67)	1.04 (0.59, 1.84)
At least one vulnerability indicator	1.38 (1.09, 1.74)	0.71 (0.42, 1.19)	1.67 (1.30, 2.14)	1.07 (0.61, 1.90)	1.18 (0.75, 1.85)

Note: Relative risk estimates were obtained from unadjusted log binomial GEE models clustering on practice (within site). Confidence intervals (CIs) are based on robust sandwich estimator standard errors.

Table 5

Multivariate Models for Imaging Availability Associated with Facility Vulnerability Indices Adjusted for Location in Urban Core

Facility Vulnerability Indices	Ultrasound RR (95% CI)	MRI RR (95% CI)	Ultrasound Guided Biopsy RR (95% CI)	MR Guided Biopsy RR (95% CI)	Stereotactic Guided Biopsy RR (95% CI)
Education: at least 15.8% of adults educated below high school graduation	0.91 (0.66, 1.27)	0.98 (0.54, 1.79)	0.95 (0.61, 1.49)	1.59 (0.86, 2.94)	1.02 (0.60, 1.74)
Race/ethnicity: at least 34.5% self-reporting minority status	1.00 (0.86, 1.16)	1.27 (0.60, 2.74)	1.40 (1.09, 1.81)	2.24 (1.06, 4.75)	1.67 (1.00, 2.78)
Income: Average census-based median income below $52,517	1.17 (0.97, 1.41)	1.58 (0.91, 2.72)	1.16 (0.79, 1.71)	1.69 (0.83, 3.44)	1.59 (0.91, 2.76)

Note: Relative risk estimates were obtained from log binomial GEE models adjusted for facility-level Rural Urban Commuting Area Codes (2 levels: urban core versus not) clustering on practice. Confidence intervals (CIs) are based on robust sandwich estimator standard errors. The vulnerability index associated with patient rurality is not presented here due to high collinearity between the rurality vulnerability index (which is derived from the rurality of patients served) and the facility location's own rurality.