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Short communication

Prevalence and correlates of false-positive results after 3-D screening mammography among uninsured women in a community outreach program

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ABSTRACT

False-positive results have been rarely investigated among uninsured minority women who undergo 3-D screening mammography. Here, we analyzed data from 21,022 women participating in the Breast Screening and Patient Navigation (BSPAN) program of North Texas with an aim to report prevalence and correlates of false-positive results after 3-D screening mammography, stratified by age. False-positives were defined as a negative diagnostic mammogram or a negative biopsy within 1 year of a positive screen. We used multivariable logistic regression to assess associations of demographic and clinical covariates and false positive results for age groups 40–49 and 50–64 years. Prevalence of false-positive results was 11.8% and 9.6% in the 40–49 and 50–64 age groups, respectively. Multivariable logistic regression demonstrated that, in the 40–49 age group, women who were non-menopausal, did not use hormone replacement therapy (HRT), and had self-reported prior mammograms had higher odds of false-positive results than those who were menopausal, used HRT and had no self-reported prior mammograms, respectively. In the 50–64 age group, women with a prior self-reported diagnostic mammogram had higher odds of false-positive results than those without a prior self-reported diagnostic mammogram. This study establishes contemporary evidence regarding prevalence and correlates of false-positive results after 3-D mammography in the unique BSPAN population, and demonstrate that use of 3-D mammography is not enough to reduce false-positive rates among uninsured women served through community outreach programs. Further research is needed to explore improved techniques to reduce false-positive rates, and ensure optimal use of scarce resources in outreach programs.

1. Introduction:

False-positive mammographic screening results, one of the most important limitations of breast cancer screening, have been rarely investigated among uninsured minority women who tend to be screened through community outreach programs (Nelson et al., 2008; Nelson et al., 2016). A false-positive result is defined as an abnormal screening mammogram followed by recall breast imaging and/or breast biopsy without subsequent breast cancer diagnosis. Negative effects of false-positive results include anxiety, distress, and lower adherence to subsequent screening (Brewer et al., 2007), in addition to economic consequences (Ong & Mandl, 2015). Although recent use of 3-dimensional (3-D) mammography has helped to reduce the prevalence of false-positive results, rates are still high and can range from 8 to 16% (Friedewald et al., 2014; Kim et al., 2021). These rates have been reported in studies conducted among predominantly non-Hispanic White and insured populations – women with access to follow up in the form of recall breast imaging and/or biopsy after an abnormal screen. We have little understanding of false-positive results among uninsured and minority women after a 3-D screening mammography. Prior studies have

Abbreviations: BSPAN, Breast Screening and Patient Navigation; NBCCEDP, National Breast and Cervical Cancer Early Detection Program; ACR, American College of Radiology; HRT, Hormone Replacement Therapy; PAP test, Papanicolaou test.

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assessed false-positive rates after 2-D mammography in facilities serving uninsured and minority populations, and have reported lower false-positive rates in these facilities compared to facilities serving less-vulnerable women (Goldman et al., 2008). However, there are no documented differences in false-positive rates based on race/ethnicity (Nelson et al., 2016). Recent increase in the use of 3-D mammography makes it imperative to understand and quantify false-positive results among uninsured and minority women. For this study, we analyzed data from more than 21,000 primarily uninsured and minority women who participated in a community outreach breast cancer screening program. Aims are to report prevalence (Aim1) and assess correlates (Aim 2) of false-positive results after 3-D screening mammography, stratified by age.

2. Materials and methods

In 1990, the Centers for Disease Control and Prevention (CDC) created the National Breast and Cervical Cancer Early Detection Program (NBCCEDP) to provide no-cost screening and diagnostic services to under- and uninsured women. Moncrief Cancer Institute created the Breast Screening and Patient Navigation (BSPAN) Program to contract with NBCCEDP and provide central reimbursement for 3-D mammography services to a regional network of participating community providers in North Texas (Argenbright et al., 2013; Inrig et al., 2017; Nair et al., 2022). After Institutional Review Board approval, informed consent was obtained from women participating in the BSPAN program. We extracted and analyzed electronic health record data for these BSPAN participants.

Analyses included women aged 40 to 64 years (eligibility criteria of NBCCEDP) if they had a 3-D screening mammogram during 2012–2019. Because this is an outreach program with a possibility of women returning for repeat screenings, we restricted analyses to the women's first screening encounter. Women with a personal history of breast cancer or of breast augmentation or reduction were excluded.

2.1. Outcome:

False-positive result was defined as positive 3-D screening mammography result followed by negative diagnostic mammography result or a negative biopsy within 1 year of the screen (Supplementary Table 1). Mammography results in 2012–2013 were reported based on terminology from fourth edition of American College of Radiology (ACR) BI-RADS Atlas, while results from 2014 to 2019 were based on the fifth edition (Spak et al., 2017). For patients who underwent mammography in 2012–2013, positive result was defined as BI-RADS categories 0, 3, 4 or 5, while negative result entailed categories 1, 2 or 3. For women who underwent mammography between 2014 and 2019, positive result included BI-RADS categories 0, 3, 4, or 5 and negative result entailed categories 1 or 2.

2.2. Measures:

We assessed potential correlates of false positives with several factors, all of which were self-reported. Demographic factors included race/ethnicity, urbanization, language preference, reading ability, and years lived in US, while clinical factors included personal history of cancer, hysterectomy, menopausal status, hormone replacement therapy (HRT), prior breast symptoms, prior Papanicolaou (PAP) test, and prior mammograms (screening and/or diagnostic). Urbanization was categorized based on 2013 rural urban continuum codes (Economic Research Service, 2013). Consistent with prior studies, results were stratified by age (40–49 and 50–64 years) (White et al., 2015).

2.3. Statistical Analysis:

We describe and compare patient characteristics using Chi-square or Fisher's exact test for categorical variables and *t*-test for continuous variables, by age group. We used univariable and multivariable logistic regression to assess associations of covariates and false positive results for each age group. As common in epidemiological studies, covariates with a p-value of < 0.2 in univariable logistic regression were included in the multivariable model (Greenland & Mickey, 1989; Nair et al., 2022). Two covariates (reading ability and years lived in the U.S.) were added to the BSPAN questionnaire in 2015. Therefore, sensitivity analysis was conducted including only those women who were enrolled after 2015, to assess the possible effect of missing data in these two variables on logistic regression results. All analyses were conducted using SAS version 9.4 and $p < 0.05$ was considered statistically significant, except in univariable logistic regression where $p < 0.2$ was considered significant.

3. Results

BSPAN provided screening mammograms to 21,746 women during 2012–2019. Of these, we excluded 724 with a history of breast cancer and analyzed data from the remaining 21,022 women. Of these, 2,262 women (10.8%) had false-positive results during their first screening encounter, while 18,760 women (89.2%) did not have false-positive results. The prevalence (Aim 1) of false-positive results during their first screening encounter was 11.8% in the 40–49 age group and 9.6% in the 50–64 age group.

Table 1 demonstrates that younger women (40–49 years) with false-positive results were predominantly Hispanic, symptomatic, non-menopausal, and did not use HRT compared to those without false positive results. Older women (50–64 years) with false-positive results were mostly non-Hispanic White compared to their counterparts without false-positive results. In both age groups, women with false-positive results had lived fewer years in the U.S. but had higher proportion of prior mammograms compared to those without false positive results.

Results of univariable and multivariable logistic regression (Aim 2) are shown in Supplementary Table 2 and Table 2, respectively. In the 40–49 age group, women who were non-menopausal, did not use HRT, and had prior self-reported mammograms (screening or diagnostic, without prior mammograms available for comparison), had higher odds of false-positive results than those who were menopausal, used HRT and had no prior self-reported mammograms (screening or diagnostic, without prior mammograms available for comparison), respectively. In the 50–64 age group, women with a prior self-reported diagnostic mammogram had higher odds of false-positive results than those without a prior self-reported diagnostic mammogram. Results of the sensitivity analysis were similar, with regards to the magnitude, direction and significance of the correlates.

4. Discussion:

To the best of our knowledge, this is the first study to report prevalence and assess correlates of false-positive results after 3-D screening mammography in an NBCCEDP program. This study is important due to the unique nature of the BSPAN population, in which women were predominantly Hispanic, uninsured, and received no-cost screening and diagnostic services through a real-world outreach program. This epidemiologic study provides an opportunity to assess 3-D screening mammography and its follow-up in light of similar populations of women who lack access to routine primary care but receive screening through community outreach programs.

The prevalence of false-positive results was 11.8% and 9.6% in the 40–49 and 50–64 age groups, respectively. These are similar to rates reported in insured, predominantly White populations. Retrospective analysis using data from thirteen sites among 173,663 women noted a false-positive rate of 8.4% after 3-D screening mammography (Friedewald et al., 2014). Another study assessed false-positive results after 3-D

Table 1
Demographic and clinical characteristics of participants by age.

Characteristics	Age group 40–49 years (n = 11,164)**** N (%)			Age group 50–64 years (n = 9,858)**** N (%)		
	False-positive (n = 1,315)	Non false-positive (n = 9,849)	p-value*	False-positive (n = 947)	Non false-positive (n = 8,911)	p-value*
Race/ ethnicity						
White	260 (19.8)	2025 (20.6)	**0.01**	414 (43.7)	3550 (39.8)	**0.01**
Black	94 (7.1)	838 (8.5)		97 (10.2)	1180 (13.2)	
Hispanic	916 (69.7)	6504 (66)		384 (40.6)	3542 (39.7)	
Other	45 (3.4)	482 (4.9)		52 (5.5)	52 (0.6)	
Rural urban continuum code						
Rural	98 (7.4)	723 (7.3)	0.15	146 (15.4)	1065 (12)	**0.02**
Near Metro	187 (14.2)	1200 (12.2)		162 (17.1)	1426 (16)	
Urban	986 (75)	7480 (75.9)		623 (65.8)	5932 (66.6)	
Language preference						
English	489 (37.2)	3935 (40)	0.09	624 (65.9)	5836 (65.5)	0.46
Spanish	806 (61.3)	5732 (58.2)		305 (32.2)	2846 (31.9)	
Other	20 (1.5)	20 (0.2)		18 (1.9)	229 (2.6)	
Reading ability**						
Poor	2 (0.3)	38 (0.7)	0.43	5 (1.1)	55 (1.1)	0.39
OK	53 (8.3)	422 (7.5)		20 (4.4)	308 (5.9)	
Good	585 (91.4)	5183 (91.8)		432 (94.5)	4817 (93)	
Mean no. of years lived in US** (Std. Dev.)						
	26.2 (14.2)	27.9 (14.2)	**<0.01**	43.8 (18.4)	44 (18.6)	**<0.01**
Symptomatic						
Yes	139 (10.6)	863 (8.8)	**0.03**	59 (6.2)	482 (5.4)	0.30
No	1,170 (89)	8931 (90.7)		886 (93.6)	8385 ((94.1)	
Personal History of cancer						
No	1313 (99.8)	9831 (99.8)	0.81	947 (100)	8883 (99.7)	0.11
Yes	2 (0.2)	18 (0.2)		0	28 (0.3)	
Prior PAP test						
No	882 (67.1)	6608 (67.1)	0.94	698 (73.7)	6554 (73.5)	0.98
Yes	433 (32.9)	3228 (32.8)		249 (26.3)	2340 (26.3)	
Prior self-reported diagnostic mammogram						
No	1202 (91.4)	9538 (96.8)	**<0.01**	890 (94)	8688 (97.5)	**<0.01**
Yes	111 (8.4)	274 (2.8)		56 (6)	191 (2.1)	
Prior self-reported screening mammogram						
No	725 (55.1)	5995 (60.9)	**<0.01**	519 (54.8)	4645 (52.1)	0.12
Yes	590 (44.9)	3854 (39.1)		428 (45.2)	4265 (47.9)	
Hysterectomy***						
No	604 (87.3)	3479 (88.2)	0.49	347 (66.2)	2536 (68)	0.40
Yes	88 (12.7)	465 (11.8)		177 (33.8)	1191 (32)	
Menopausal						
No	627 (47.7)	4055 (41.2)	**<0.01**	137 (14.5)	1399 (15.7)	0.32
Yes	688 (52.3)	5794 (58.8)		810 (85.5)	7512 (84.3)	
Hormone Replacement Therapy (HRT)						
No	1254 (95.4)	9059 (92)	**0.01**	861 (91)	8009 (89.9)	0.70
Yes	50 (3.8)	528 (5.4)		77 (8.1)	682 (7.7)	

*p-values<0.05 are statistically significant.
** Data collected only during the later stages of BSPAN.
*** Data collected only during the initial stages of BSPAN.
****Values do not add to column total due to missing data.

screening mammography and noted a false-positive rate of 16.3% among 82,664 women. (Kim et al., 2021). Although these studies did not stratify false-positive rates by age, prior studies using 2-D mammography have reported higher rates of false-positive results among younger women (McGuinness et al., 2018; Nelson et al., 2016). Thus, our results are consistent with the literature in two aspects: prevalence of false-positive rates in our study is comparable to those among insured population using 3-D mammography, and we found higher false-positive rates among younger women, compared to older women, similar to those after 2-D mammography.

We assessed correlates associated with false-positive results, and noted findings similar to those reported in prior studies using 2-D mammography among insured populations (Román et al., 2012) – younger pre-menopausal women demonstrated higher odds of false-positive results than younger post-menopausal women, and there was no significant association between race and false-positive results (Honig et al., 2019; Nelson et al., 2016).

On the other hand, our assessment of correlates also revealed some significant associations novel to this unique population that should be evaluated further in future research. A unique finding in our study was among younger women, where those who did not use HRT had higher odds of false-positive results than those using HRT. This is inconsistent with previous studies that included younger women and reported a positive association between false-positive results and HRT (Hubbard et al., 2011; Román et al., 2012).

We also found a unique association of false-positive results with prior self-reported mammograms (screening and diagnostic). Younger women who self-reported having undergone prior mammographic screening, without priors being available for comparison, had significantly higher odds of false-positive results compared to younger women who reported no prior screens. Similarly, women in both age groups with self-reported prior diagnostic mammogram had significantly higher odds of false-positive results compared to those with no reported prior diagnostic mammogram. Our finding that prior self-reported screening or

Table 2
Odds ratio for factors associated with false-positive results stratified by age.

Characteristics*	Age group 40–49 years			Age group 50–64 years		
	Adjusted Odds Ratio	95% Confidence Interval	p-value**	Adjusted Odds Ratio	95% Confidence Interval	p-value**
Race/ ethnicity						
White	Ref					
Black	0.88	0.68–1.14	0.69	0.77	0.60–1.13	0.12
Hispanic	1.00	0.79–1.26	0.36	1.00	0.86–1.16	0.05
Other	0.81	0.57–1.15	0.31	0.79	0.58–1.08	0.34
Rural urban continuum code						
Rural	Ref					
Near Metro	0.99	0.76–1.30	0.82	0.77	0.61–1.20	0.19
Urban	0.94	0.75–1.18	0.44	0.78	0.64–1.08	0.09
Language preference						
English	Ref					
Spanish	1.10	0.89–1.36	0.86			
Other	1.28	0.76–2.15	0.45			
Mean no. of years lived in US (Std. Dev.)						
	0.99	0.98–1.00	0.09			
Symptomatic						
Yes	Ref					
No	1.27	0.86–1.77	0.10			
Prior self-reported diagnostic mammogram						
No	Ref					
Yes	2.59	2.05–3.28	**<0.01**	1.76	1.30–2.37	**<0.01**
Prior self-reported screening mammogram						
No	Ref					
Yes	1.27	1.11–1.45	**<0.01**	0.86	0.75–1.02	0.06
Menopausal						
No	Ref					
Yes	0.73	0.64–0.83	**<0.01**			
Hormone Replacement Therapy (HRT)						
No	Ref					
Yes	0.67	0.49–0.93	**0.02**			

*$p < 0.2$ was considered statistically significant for univariable logistic regression and only those characteristics with $p < 0.2$ entered the multivariable logistic regression model.
**p-value < 0.05 was considered statistically significant for multivariable logistic regression model.

diagnostic mammogram increases the risk of subsequent false-positive rates is in contrast to existing literature finding that false-positive rates are highest during first screening encounter and reduced for subsequent screens (Hubbard et al., 2011). However, the studies showing association of prior screens with lower false-positive rates have been in the context of availability of previous films for comparison (Hubbard et al., 2011). In contrast, our study included only self-reports of prior screening and diagnostic mammograms. Lack of previous films available to the radiologist for comparison may explain why false-positives were not lower among women with previous mammograms, but why false-positives were higher in this group is a remaining question.

Our study has some limitations. Results are based on data from a real-world outreach program serving uninsured women, where the program does not constitute their primary medical home, and thus may not be generalizable to women in other clinical contexts. Also, our use of existing clinical records data restricted availability of other important covariates such as familial breast cancer, breast density, and behavioral factors. Some important data, such as prior screening and diagnostic experience, are based on self-report that could not be verified from healthcare records prior to participation in the BSPAN screening program. Additionally, due to the nature of the outreach program, women were free to attend any healthcare provider within the hub-and-spoke network to receive screening and follow-up diagnostic services. Because these women were not nested within a primary medical home, we lacked the ability to explore clustering effects via advanced statistical methods that have been used in other studies (Hubbard et al., 2011; Nelson et al., 2016). We were also limited in our ability to assess cumulative probability of false-positive rates in our study population. Other studies assessing cumulative false-positive rates in insured populations have reported greater than 50% women returning for repeat screens (Hubbard et al., 2011). The repeat screening rate in our population within 30 months from the first screen was significantly lower (28.1%) (Nair et al., 2022), which may lead to an under-estimation of cumulative false-positive rates.

Despite these limitations, our findings are important because they help establish contemporary evidence regarding prevalence of false-positive rates after 3-D screening mammography in uninsured women, and demonstrate that women receiving no-cost screening and diagnostic services through the NBCCEDP program have false-positive screening rates similar to insured women. These findings suggest that use of 3-D mammography is not enough to reduce false-positive rates among uninsured women. Further research is needed to explore evidence-based techniques to reduce false-positive rates, thereby ensuring optimal use of scarce resources in community outreach programs serving uninsured and underserved women.

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CRediT authorship contribution statement

Rasmi G. Nair: Conceptualization, Methodology, Data curation, Formal analysis, Writing – original draft. **Simon J. Craddock Lee:** Conceptualization, Writing – review & editing, Supervision, Funding acquisition. **Hong Zhu:** Methodology, Formal analysis, Writing – review & editing. **Firouzeh K. Arjmandi:** . **Emily Berry:** Investigation, Data curation, Writing – review & editing. **Keith E. Argenbright:**

Methodology, Writing – review & editing, Writing – review & editing, Funding acquisition. **Jasmin A. Tiro:** Writing – review & editing, Funding acquisition. **Celette Sugg Skinner:** Conceptualization, Methodology, Resources, Writing – review & editing, Supervision, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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