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Understanding mechanisms of racial disparities in breast cancer: an assessment of screening and regular care in the Carolina Breast Cancer Study

Matthew R. Dunn[1,2] · Eman M. Metwally[1,2] · Sanah Vohra[2,8] · Terry Hyslop[3] · Louise M. Henderson[2,4] · Katherine Reeder-Hayes[2,5] · Caroline A. Thompson[1,2] · Jennifer Elston Lafata[2,6] · Melissa A. Troester[1,2,7] · Eboneé N. Butler[1,2]

Abstract

Purpose Screening history influences stage at detection, but regular preventive care may also influence breast tumor diagnostic characteristics. Few studies have evaluated healthcare utilization (both screening and primary care) in racially diverse screening-eligible populations.

Methods This analysis included 2,058 women age 45–74 (49% Black) from the Carolina Breast Cancer Study, a population-based cohort of women diagnosed with invasive breast cancer between 2008 and 2013. Screening history (threshold 0.5 mammograms per year) and pre-diagnostic healthcare utilization (i.e. regular care, based on responses to "During the past ten years, who did you usually see when you were sick or needed advice about your health?") were assessed as binary exposures. The relationship between healthcare utilization and tumor characteristics were evaluated overall and race-stratified.

Results Among those lacking screening, Black participants had larger tumors (5 + cm) (frequency 19.6% vs 11.5%, relative frequency difference (RFD) = 8.1%, 95% CI 2.8–13.5), but race differences were attenuated among screening-adherent participants (10.2% vs 7.0%, RFD = 3.2%, 0.2–6.2). Similar trends were observed for tumor stage and mode of detection (mammogram vs lump). Among all participants, those lacking both screening and regular care had larger tumors (21% vs 8%, RR = 2.51, 1.76–3.56) and advanced (3B +) stage (19% vs 6%, RR = 3.15, 2.15–4.63) compared to the referent category (screening-adherent and regular care). Under-use of regular care and screening was more prevalent in socioeconomically disadvantaged areas of North Carolina.

Conclusions Access to regular care is an important safeguard for earlier detection. Our data suggest that health equity interventions should prioritize both primary care and screening.

Keywords Healthcare · Disparities · Cancer screening · Mammography · Tumor presentation · Cohort study

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Melissa A. Troester and Eboneé N. Butler are co-senior authors.

✉ Matthew R. Dunn
mdunn@unc.edu

✉ Melissa A. Troester
mdunn@unc.edu

1 Department of Epidemiology, University of North Carolina at Chapel Hill, 135 Dauer Drive, Chapel Hill, NC 27599, USA

2 Lineberger Comprehensive Cancer Center, University of North Carolina, Chapel Hill, NC, USA

3 Sidney Kimmel Cancer Center, Thomas Jefferson University, Philadelphia, PA, USA

4 Division of Pulmonary Disease and Critical Care Medicine, Department of Radiology, University of North Carolina, Chapel Hill, NC, USA

5 Division of Oncology, School of Medicine, University of North Carolina, Chapel Hill, NC, USA

6 Eshelman School of Pharmacy, University of North Carolina, Chapel Hill, NC, USA

7 Department of Pathology and Laboratory Medicine, University of North Carolina, Chapel Hill, NC, USA

8 David Geffen School of Medicine, University of California, Los Angeles, USA

Introduction

Despite similar rates of diagnosis as White women, Black women are approximately 40% more likely to die from breast cancer [1, 2]. One reason for this survival disparity is that Black women are more likely to be diagnosed with later stage tumors (larger and more locally advanced) which may be refractory to curative treatments and more likely to recur after treatment [3, 4]. Screening mammography is critical for early detection, and there is growing interest in individually customized risk assessments to determine potential benefit from earlier and more frequent screenings [5–7]. Some of these proposals have suggested that Black women should be targeted for such assessments due to elevated prevalence of earlier onset and aggressive tumors such as the "triple negative" subtype [8–11].

However, the prevalence of aggressive subtypes at diagnosis may also reflect underuse of primary care. Having a reliable and consistent source of regular healthcare ("regular care") is an important safeguard for overall health, and prior theoretical models suggest that regular outpatient care can both directly and indirectly (through mammography) support earlier cancer detection [12–16]. Studies have shown that emergency room cancer diagnoses are associated with poorer cancer outcomes, however, few studies have evaluated the combined effect of screening and regular care on breast cancer tumor characteristics, and to our knowledge no prior studies have assessed this effect in relation to Black-White disparities [16, 17]. This is a critical area for further inquiry, as understanding root causes of inequity in the cancer healthcare continuum is necessary to define health equity interventions [18, 19].

In our study, we leveraged data from a racially diverse cohort of screening age women (age 45 and older) diagnosed with breast cancer in North Carolina, USA. The objectives of this study were (1) to estimate how tumor characteristics at diagnosis vary according to regular care and screening history (as separate and cross-classified exposures); (2) to evaluate how differences in regular care and screening history manifest as tumor characteristics in Black and non-Black patients, and (3) to evaluate whether patients underserved in regular care and screening aggregate by geographic region of the state.

Methods

Data source and study population

The Carolina Breast Cancer Study Phase III (CBCS3) is a population-based cohort of 2,998 women diagnosed with invasive breast cancer, encompassing 44 counties in central and eastern North Carolina. English-speaking women were eligible for inclusion if they were diagnosed with a first primary breast cancer between 2008 and 2013 [20]. Participants were identified by random selection through a rapid case ascertainment process used by the North Carolina Cancer Registry. Black and younger women were oversampled using a randomized recruitment strategy that resulted in half of the study population identifying as Black and half of the study population aged 50 years or younger. CBCS measures race by self-classification and is intended to conceptualize race as a socially constructed identity, rather than a measure of genetic ancestry [21]. For this analysis, participants were grouped as Black or non-Black; 95% of the latter group are non-Hispanic White women. We restricted this analysis to women age 45 years old or older ($N = 2,058$), consistent with relevant age at recommended screening in most guidelines at the time of data collection [5, 6].

Study nurses conducted a baseline interview during in-home visits, which took place on average 5 months post-diagnosis. Socio-demographic information and preventive healthcare history (screening history and regular care) were ascertained during the interview. Tumor characteristics and treatment data were abstracted from medical records and pathology reports. Additional methodological information on the Carolina Breast Cancer Study Phase 3 has been described previously [22]. All study protocols were adherent to ethical standards of the institutional review board of the University of North Carolina at Chapel Hill, which approved the study.

Health care and screening exposure

Two forms of healthcare were considered in this analysis: screening history and regular care. For regular care, participants were asked at baseline "During the past ten years, who did you usually see when you were sick or needed advice about your health?" Participants who selected "general practitioner/family doctor/regular doctor" were classified as regular care users. Participants who selected "specialist such as heart, lung, or kidney doctor" were also classified as regular care users. Participants who selected "emergency room or urgent care doctor," "local health department doctor or health advisor," "other," or did not indicate any source of care were defined as lacking regular care. Thus, participants were classified as having (1) regular care or (2) no regular care; these categories were intended to represent access to a reliable source of care, rather than a quantitative measure of utilization.

For screening history, participants were asked "how many mammograms did you have?" during each of 3 age intervals: before age 40, between 40 and 50, and after 50. To estimate

lifetime rate of screening mammography, we first excluded any mammograms received before age 40 because breast cancer screening is much less frequent in this population, and has not been recommended for women under age 40 since before 1992 [23, 24]. Participants were also asked the number of mammograms received in the past two years, and these were excluded from the screening total to reduce exposure misclassification due to diagnostic mammography. Finally, total mammograms were divided by the number of years lived from age 40 through 2 years prior to diagnosis (to exclude diagnostic mammography). This measure of mammography represents a scale of relative use rather than an exact, quantitative representation of actual rates of screening mammography. Participants with at least 0.5 mammograms/year were classified as screening-adherent for our analysis based on guidelines from the United States Preventive Services Task Force (USPSTF) which recommend most women ages 40–74 years receive one screening mammogram every 2 years [5].

Given the self-reported and inexact method of mammography exposure in our analysis, we conducted sensitivity analyses using alternate definitions for screening adherence, accounting for potential misclassification in either direction. In addition to 0.5 mammograms/year (as in the main analysis), we assessed the screening models using a higher threshold for mammography adherence (0.7 mammograms/year) and a lower threshold (0.3/year).

Breast cancer characteristics

Tumor characteristics at diagnosis, including AJCC stage, tumor size, and grade were obtained from participant medical records. In the regression analyses, participants with stage IIIB, IIIC, and IV cancers were combined as one "advanced stage" group [25]. High grade was defined as grade 3 and large tumor size was defined as 5 + cm. Self-reported mode of detection was assessed in the baseline study interview where participants reported if their breast cancer was first detected by routine screening, lump noticed by self/partner/doctor, or other/ultrasound. For this analysis, we excluded 260 women who reported other/ultrasound and compared those who reported screening- or lump-detected cancer.

Under our interpretation of race as a social construct, we hypothesized that patterns in healthcare utilization would be related to multilevel social exposures that differ by race. Therefore, we considered several additional factors that measure individual- and community-level social exposures. Individual-level socio-demographic information was obtained from the baseline interview, including race, age, income, education, and insurance status. Urbanicity was obtained from the National Cancer Institute's Census Tract-level SES and Rurality Database, which defines urban census

tracts as those with rural–urban commuting area (RUCA) codes 1.0, 1.1, 2.0, 2.1, 3.0, 4.1, 5.1, 7.1, 8.1, and 10.1; all other codes are defined as rural [26, 27]. Breast cancer subtype (ER + /HER2-, ER-/HER2 + , or triple negative) was derived from hormone receptor status in pathology reports. Neighborhood-level SES was defined as a binary indicator (high/low) for 2 variables: "Assets" which captures the presence of beneficial factors such as education attainment or home value; and "Deprivation" which captures the presence of disadvantageous factors such as unemployment or household crowding. These measures were previously developed from census tract-level American Community Survey data; detailed methods have been published by Larsen and colleagues [28]. County-level poverty designation was extracted from the Agency for Healthcare Research and Quality SDoH dataset [29]. County-level primary care provider density was obtained from the Sheps Healthcare Workforce dataset [30].

Statistical analysis

Descriptive statistics were reported overall and by race. Differences in tumor characteristics by regular care source and screening adherence were assessed for statistical significance using Chi-square tests. Correlations of screening rate with regular care and participant race were assessed by examination of kernel density plots. To identify potential geographic patterns in screening or regular care, we described the prevalence of both forms of care according to sub-regional, county, and census tract boundaries within North Carolina. State sub-regions were defined according to previous methodology used by our group [31], based on regional Area Health Education Centers (AHECs), which support healthcare workforce recruitment and professional development in their respective regions [32].

Associations of regular care and screening with tumor characteristics at diagnosis were assessed by risk ratios (RRs) and 95% confidence intervals (CIs), estimated from log-binomial regression models. Regular care and screening were first assessed separately, and we then created a 4-level nominal variable based on cross-classification of these. We evaluated each exposure classification in association with tumor characteristics overall and in race-stratified models. Additionally, we report race-stratified risk estimates for each exposure-outcome combination, so that the potential influence of screening adherence or regular care could be assessed on both a ratio and absolute scale [33, 34]. We initially considered adjusting for age and cancer subtype as well, given prior literature indicating associations with tumor presentation at diagnosis [11, 35, 36]. However, RR estimates were not meaningfully different before and after adjustment for these 2 variables, and were excluded from the final models. Analysis and figure preparation for this article were performed in SAS version 9.4 and RStudio 3.0 [37, 38].

Results

Socio-demographic characteristics of the CBCS population are presented overall and stratified by race in Table 1. The study sample (N = 2,058) was 49% Black, 56% with annual income $50,000 or less, and 68% with at least some college education. Most women (88%) relied on regular care and 67% were classified as screen adherent. Black women were more likely than non-Black women to lack regular care (17% vs 7%) and to have been never screened (15% vs 8%).

Demographic and healthcare characteristics were measured during in home interviews at study baseline, which took place at median 5 months post-diagnosis. Community assets and deprivation were previously defined according to census-tract level American Community Survey (ACS) data. Rurality was defined at the census-tract level based on the U.S. Department of Agriculture (USDA)'s Rural Urban Commuting Area (RUCA) codes. Screening categories are based on number of mammograms/year, grouped as follows: < 0.33, 0.33–0.49, 0.5 + . The United States Preventive Services Task Force (USPSTF) recommends most women ages 40–74 years receive one screening mammogram every 2 years (I.E. 0.5 mammograms per year). For subsequent analyses, women with less than recommended screening and

Table 1 Demographic and healthcare characteristics of CBCS III participants, age 45 years and older (N = 2,058)

| | All participants | Participant race | |
| | | Non-Black | Black |
Characteristic	N (%)	N (%)	N (%)
Total	N = 2,058	N = 1,052	N = 1,006
Income			
< $20,000	461 (24%)	119 (12%)	342 (36%)
$20,000 to $50,000	627 (32%)	277 (28%)	350 (37%)
More than $50,000	858 (44%)	599 (60%)	259 (27%)
Insurance			
Private insurance	1,429 (69%)	838 (80%)	591 (59%)
Medicare	278 (14%)	65 (6.2%)	213 (21%)
Medicaid	220 (11%)	113 (11%)	107 (11%)
Other	12 (0.6%)	5 (0.5%)	7 (0.7%)
No insurance	118 (5.7%)	30 (2.9%)	88 (8.7%)
Education			
Any college	1,400 (68%)	779 (74%)	621 (62%)
High school graduate (or GED) or less	658 (32%)	273 (26%)	385 (38%)
Community assets			
High	858 (42%)	574 (55%)	284 (28%)
Low	1,200 (58%)	478 (45%)	722 (72%)
Community deprivation			
High	822 (40%)	227 (22%)	595 (59%)
Low	1,236 (60%)	825 (78%)	411 (41%)
Rurality			
Urban	1,761 (86%)	910 (87%)	851 (85%)
Rural	297 (14%)	142 (13%)	155 (15%)
Source of care reliance in 10 years preceding diagnosis			
Primary care	1,681 (82%)	890 (85%)	791 (79%)
Specialist	130 (6.3%)	86 (8.2%)	44 (4.4%)
ER/urgent care	185 (9.0%)	62 (5.9%)	123 (12%)
Health department/other	52 (2.5%)	8 (0.8%)	44 (4.4%)
No source of care	10 (0.5%)	6 (0.6%)	4 (0.4%)
Adherence to USPSTF screening guidelines			
Never screened	233 (12%)	88 (8%)	148 (15%)
Less than recommended	447 (22%)	219 (21%)	228 (23%)
As recommended	1,375 (67%)	745 (71%)	630 (63%)

no screening at all were combined as one "non-adherent" group in accordance with these recommendations.

Tumor characteristics (separate exposures)

We observed differences in tumor characteristics at diagnosis between women with and without a source of regular care. Overall, lack of regular care was associated with advanced stage (RR, 95% CI = 1.73, 1.22–2.47) and large tumor size (RR = 1.78, 1.32–2.41) (Table 2, Fig. 1a), while associations for grade, and ER⁻/HER2⁺, ER⁺/HER2⁻, or triple negative tumor subtype (TNBC) did not differ significantly by regular care. Participants lacking regular care were also more likely to report that their cancer was detected by a lump rather than a routine mammogram (RR = 1.42, 1.28–1.59). These patterns were similar in Black and non-Black women (Table 2, Fig. 1b).

With respect to screening adherence, under-screened women had higher frequency of large tumors (RR = 1.89, 1.48–2.41), advanced stage (RR = 2.40, 1.80–3.19), and detection by lump (RR = 1.54, 1.41–1.68) (Table 3, Fig. 1c). A borderline association was also detected with high grade: RR = (1.12, 1.00–1.25). In race-stratified analyses, screening non-adherence was significantly associated with advanced

breast cancer presentation for both Black and non-Black women (Table 3, Fig. 1d), with slightly higher RR estimates among Black women. That is, the RR for advanced stage in association with under-screening was (2.53, 1.67–3.82) for Black and (1.84, 1.17–2.90) for non-Black women. For large tumor size, there was also a slightly higher association among Black women (RR = 1.80, 1.30–2.50) compared to non-Black (RR = 1.33, 0.89–1.99).

We performed sensitivity analyses with alternate thresholds for screening adherence (0.3 and 0.7 mammograms/ year), reclassifying 165 (8%) and 253 participants (12%), respectively. Overall, the RRs were similar (to results in Fig. 1c and 1d) under alternate thresholds and statistical significance was unchanged (Supplementary Fig. 1).

Tumor characteristics (cross-classified exposure)

To assess whether regular care may influence screening, we evaluated the association between the two (Fig. 2a), and when restricting to those with regular care, the rate of mammography was indistinguishable for Black vs. non-Black women (Fig. 2b). We then examined patterns of tumor characteristics considering regular care and screening as combined exposures. Considering the doubly exposed (lacking regular care and under-screened), these participants were at greatest risk for unfavorable tumor characteristics (Fig. 2c,

Table 2 Tumor characteristics by regular care and screening adherence (N = 2,058)

	Regular care, screened N = 1,293	No regular care, screened N = 82	Regular care, under-screened N = 518	No regular care, under-screened N = 165	P-value
Clinical subtype					> 0.05
ER−/HER2+	61 (5.3%)	4 (5.6%)	28 (6.2%)	11 (8.1%)	
ER+/HER2−	853 (75%)	52 (72%)	335 (74%)	99 (73%)	
TNBC	230 (20%)	16 (22%)	91 (20%)	26 (19%)	
Unknown	149	10	64	29	
Tumor size, cm					< 0.001
< 2	803 (62%)	48 (59%)	238 (46%)	49 (30%)	
2 to 5	380 (29%)	24 (29%)	200 (39%)	82 (50%)	
5 +	106 (8.2%)	10 (12%)	74 (14%)	34 (21%)	
Stage					< 0.001
1	660 (51%)	38 (47%)	189 (37%)	34 (21%)	
2	469 (36%)	34 (42%)	208 (40%)	76 (46%)	
3/4	164 (13%)	9 (11%)	120 (23%)	55 (33%)	
Grade					< 0.01
1	312 (24%)	20 (24%)	87 (17%)	20 (12%)	
2	488 (38%)	30 (37%)	213 (42%)	71 (44%)	
3	476 (37%)	32 (39%)	208 (41%)	72 (44%)	
Mode of detection					< 0.001
Routine mammogram	710 (55%)	39 (48%)	191 (37%)	37 (22%)	
Found lump	485 (38%)	36 (44%)	281 (54%)	108 (65%)	
Other[a]	98 (7.6%)	7 (8.5%)	46 (8.9%)	20 (12%)	

*Indicates significant p value (threshold alpha = 0.05) computed from Chi-square tests (except for stage where Fisher's test was used)
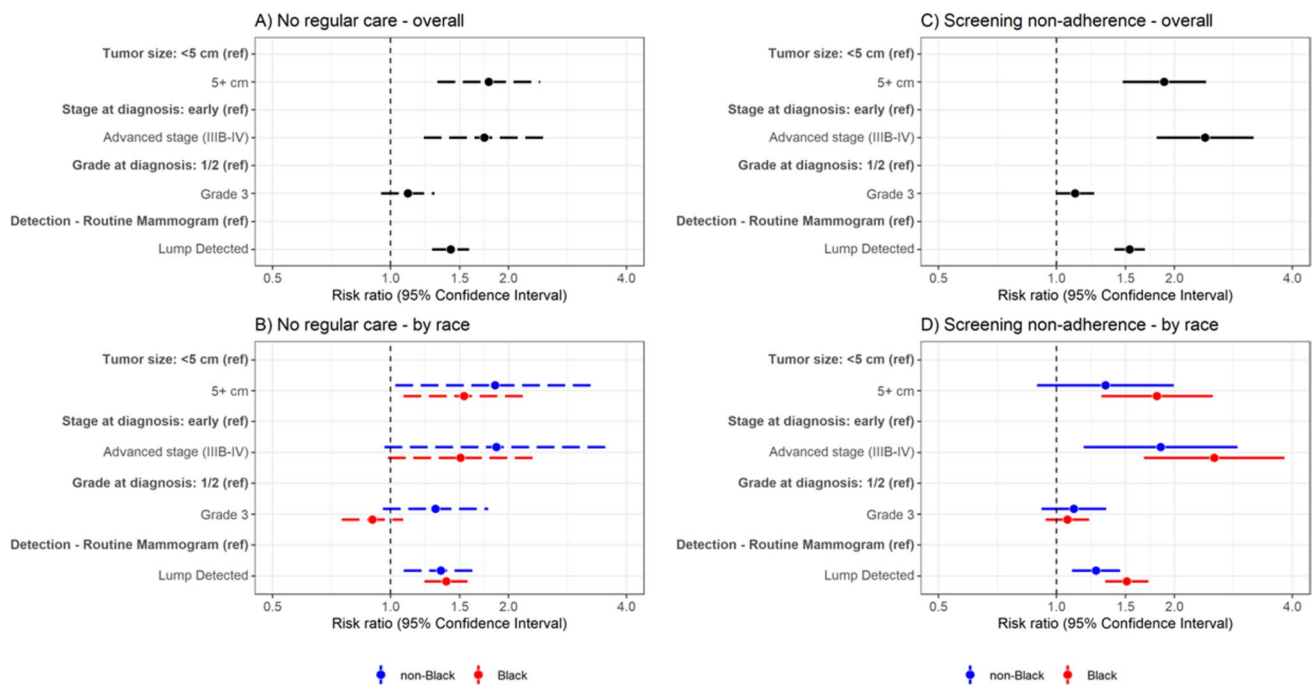
Fig. 1 Tumor characteristics according to regular care and screening. Risk ratios (RR) and 95% confidence intervals were estimated from bivariate log-binomial regression models. Estimates represent the relative risk of the indicated outcome for those lacking care compared to those with care. Results are shown for A) no regular care, B) no regular care—by race, C) non-adherence to biennial screening, and D) non-adherence to biennial screening—by race

Table 3 Racial differences (Black compared to non-Black) in tumor characteristics according to regular care and screening

Outcome	No regular care RFD (95% CI)	Regular care RFD (95% CI)	Under-screened RFD (95% CI)	Screened RFD (95% CI)
Tumor size > 5 cm	4.8% (-5.1, 14.7)	4.7% (1.9–7.5)	8.1% (2.8, 13.5)	3.2% (0.2,6.2)
Grade 3	7.3% (-5.9, 20.6)	21.0% (16.6–25.5)	18.2% (10.9,25.5)	19.9% (14.8,25.0)
Advanced stage (3B+)	2.3% (-6.7, 11.2)	3.0% (0.5–5.5)	5.5% (0.4, 10.6)	1.4% (-1.1, 3.9)
Lump detection	11.7% (-2.1, 25.6)	7.2% (2.4, 11.9)	13.5% (5.9, 21.1)	4.6% (-0.8,10.1)

Table 2). They had higher risk of large tumor size (21% vs 8%, RR = 2.51, 1.76–3.56), advanced stage (19% vs 4%, RR = 3.15, 2.15–4.63), and detection by lump (65% vs 38%, RR = 1.84, 1.63–2.06). Those with either under-screening or lacking regular care (but not both) also had higher tumor size, stage, and detection by lump. Finally, the effect of regular care appeared to be strongest among the under-screened. For example, the comparison of large size tumor frequency between regular care and no regular care participants was 14% vs 21% among the under-screened, while this contrast was smaller (8% vs 12%) among the screened. A similar pattern was observed for advanced stage.

Racial and geographic disparities

Regular care was associated with decreased frequency of aggressive tumor presentation in both racial groups, but Black women still had higher frequency of most adverse tumor factors (Fig. 3a). Screening-adherence was also associated with reduced frequencies of unfavorable tumor characteristics for all participants, but in contrast, screening appeared to attenuate differences by race (Fig. 3b, Table 3). For those without screening, Black women were more likely to have large tumor size (19.6% vs 11.5%, Relative frequency difference (RFD) = 8.1%, 2.8–13.5%), advanced stage (16.3% vs 10.8%, RFD = 5.5%, 0.4–10.6%), and lump detection (69.1% vs 55.6%, RFD = 13.5%, 5.9–21.1%). For those with screening, although Black women were still more likely to have unfavorable tumor characteristics, race differences were reduced for large size (10.0% vs 7.2%, RFD = 3.2%, 0.2–6.2%), advanced stage (6.5% vs 5.1%, RFD = 1.4%, − 1.1 to 3.9%), and lump detection (43.5% vs 38.9%, RFD = 4.6%, − 0.8 to 10.1%).

Given that screening and regular care were correlated and statistically and significantly associated with worse tumor outcomes, we explored whether these healthcare factors
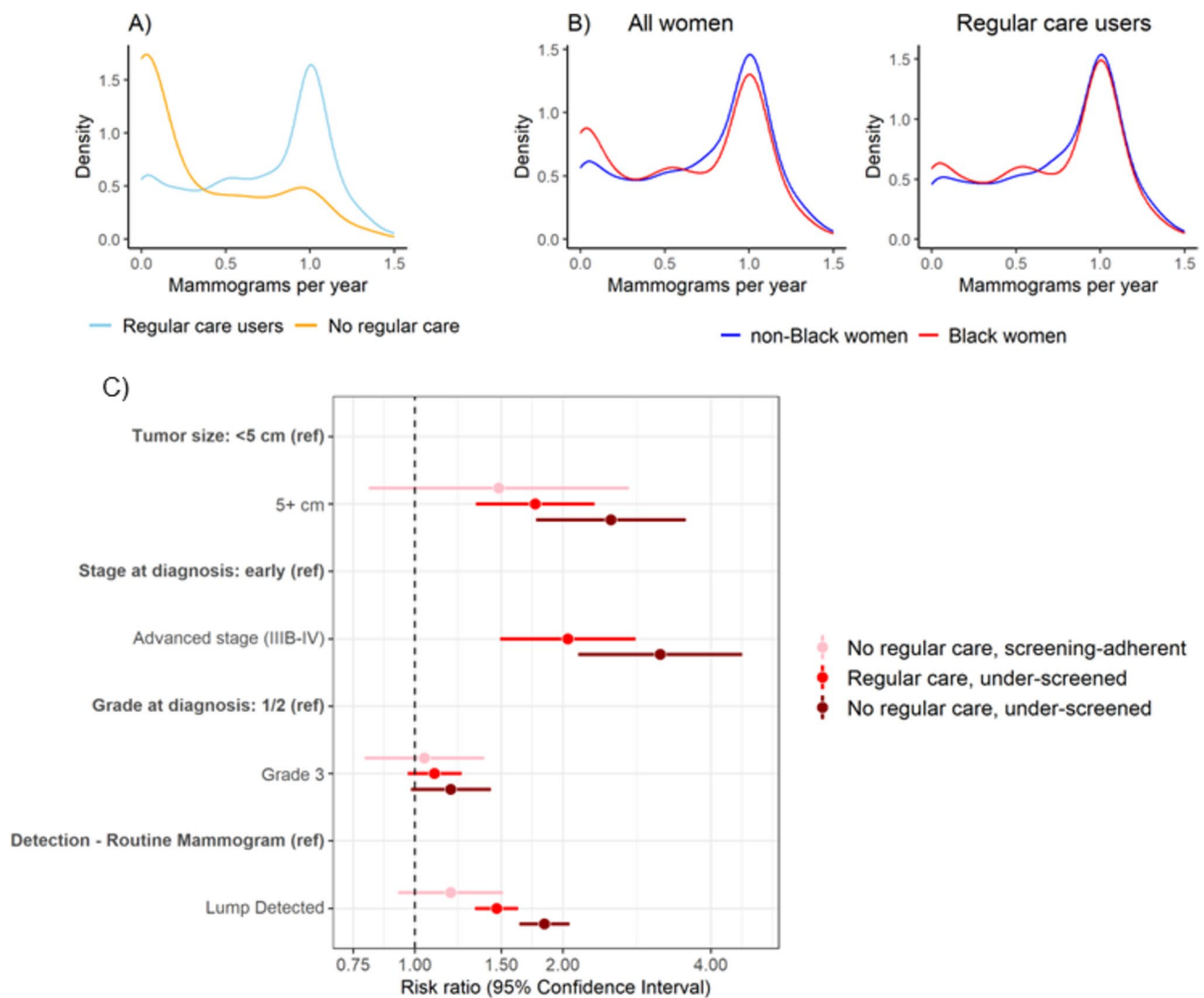
Fig. 2 Simultaneous assessment of regular care and screening. Kernel density plots show a smoothed, non-parametric distribution of mammography receipt (units of screening mammograms per year). Distributions are compared **A** between participants with and without regular care, and **B** between Black and non-Black participants overall with restriction to participants with regular care. **C** Risk ratios and confidence intervals were estimated from log binomial regression models. Each estimate corresponds to the relative risk for the 3 comparator groups relative to the reference group. The reference group includes participants with regular care and screening adherence. The "double exposed" index group include participants without regular care and are non-adherent to screening guidelines. The advanced stage RR for no regular care, screening-adherent is not shown because there were only 3 participants in this exposure-outcome group and the CI was not stable.

varied geographically. We report difference by geographic sub-region (largest loci of analysis), county, and census tract (smallest). At the sub-region level, under-screening and lack of regular care were more prevalent in the eastern Area Health Education Centers (AHEC regions; Area L, Eastern, Southern, Southeast) (Supplemental Table 3). Participants living in high-poverty counties were twice as likely to lack both forms of care (14% vs 7%). Under-screening was more prevalent in counties with fewer primary care providers per capita, but there was no relation with regular care. There were also associations at the census tract-level, as participants living in low-asset and high-deprivation areas had lower rates of screening and regular care.

Discussion

In this analysis, we evaluated two measures of preventive healthcare—regular office care and mammography screening—with tumor characteristics in a racially diverse sample ($N = 2,058$) of women aged 45–74 diagnosed with breast cancer in North Carolina. Among both Black and

Fig. 3 Racial differences in tumor characteristics by receipt of regular care and screening. Frequency (expressed as a percentage) of unfavorable tumor characteristics are reported for Black and non-Black women according to receipt of preventive care. Results are shown for **A** regular care and **B** screening
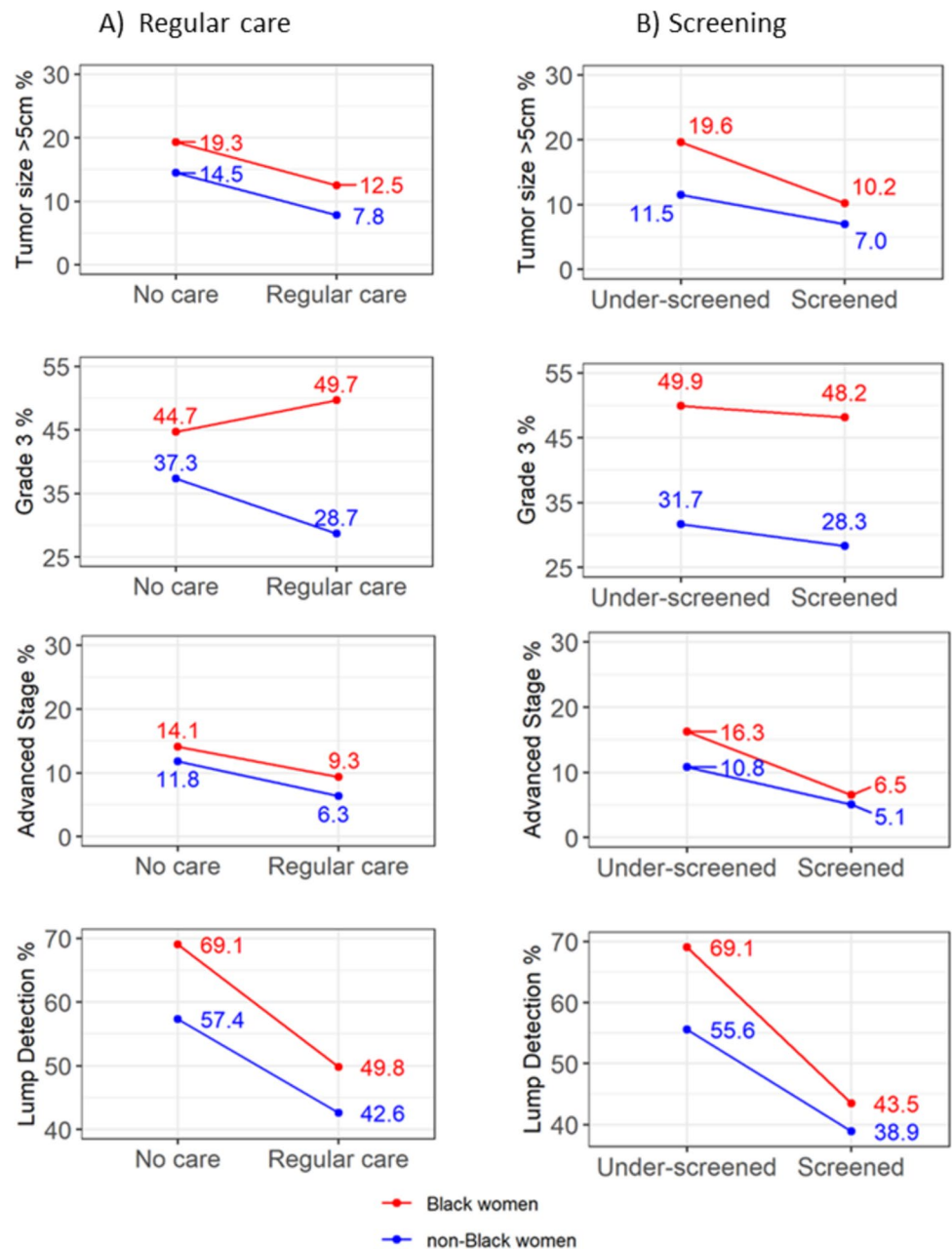
non-Black women, lower mammography screening and lack of regular care were associated with more aggressive tumor characteristics and greater frequency of symptomatic detection (by lump). The magnitude of these associations was largest for women lacking both forms of care. We found significant RRs for tumor features that depend on time (size, stage), but not a tumor feature that is thought to be intrinsic to tumor biology (grade), suggesting that the mechanism of shift toward aggressive tumors is tumor latency time rather than intrinsic biological differences. Furthermore, we found that racial differences in tumor characteristics were attenuated when restricting to screening-adherent women.

These findings underscore potential for screening-focused interventions to reduce racial disparities in breast cancer. Presently, national mammography rates in the U.S. are similar between Black and White women [39]. However, screening inequalities are still observed in some patient populations and breast cancer survivorship remains worse for Black women [40–42]. The mitigation of race differences in the screening-adherent subset of our study suggests that there is potential to close the equity gap in breast cancer by targeting screening: More than a third of Black women in the study were under-screened (38%), compared to lower proportions in non-Black women (29%), although proportions of under-screened are too

high in both groups. The protective effect of screening could also be stronger in Black women because this group has greater rates of late-stage diagnosis. When assessing effect of under-screening, the race-stratified RR estimates were larger in magnitude for Black women compared to non-Black for advanced stage (RRs: 2.53 vs 1.84) and large tumor size (RRs: 1.81 vs 1.33), respectively. Interpretation of difference should be strongly cautioned; however, as for each outcome the 95% confidence intervals were overlapping between racial groups.

Our results are consistent with recent studies that suggest increasing breast cancer screening among Black women is an important step to advance health equity. Chen and colleagues conducted a cross-sectional study among 415,277 breast cancer deaths in the US from 2011 to 2020 [35]. Using the 10-year breast cancer mortality rate in the overall population at age 50 as a benchmark, the age when many women commence screening, they found that Black women reached this risk threshold at age 42 (compared to White women at age 51). There was also a simulation study which evaluated mortality, equity, and efficiency for 9 different screening strategies according to age of commencement and interval [10]. While commencing biennial screening at age 45 for Black women was most efficient (in terms of life years gained per mammogram), the most equitable scenario (in terms of reducing Black/White gaps in mortality) included biennial screening starting at age 40 for Black women. These apparent benefits of earlier screening among Black women may reflect a mechanism where screening counteracts other barriers to quality healthcare linked to racism, discrimination, and higher risk of younger onset and fast growing subtypes [43, 44]. Given that randomly controlled trails that inform breast cancer screening recommendations have been conducted in largely White study populations, further research is needed to optimize screening among younger Black women [45, 46].

The value of breast cancer screening in cancer prevention and control is well documented, but regular care is less studied as a factor in tumor presentation [47–51]. Recent studies have found that primary care use was associated with decreased frequency of metastatic or late-stage cancer at multiple sites—including breast, colorectal and other sites [52–55]. One study found that greater care utilization was associated with breast cancer diagnostic delays in an Ontario, CA population [56], but their definition of care utilization combined office-based visits, emergency department visits, and hospital admissions and therefore likely reflects health status rather than primary care utilization. In emergency settings, detected cancers are more frequently symptomatic and advanced [12–15]. Considering our results and prior literature, primary or office/appointment-based care is an important component of a health care strategy for earlier cancer detection.

The strength of our study was assessment of both regular care and screening history as predictors of breast cancer tumor characteristics. Most comparable studies on screening or healthcare patterns have only considered one of these, although there were 2 studies among Medicare beneficiaries which did consider both forms of care [16, 17]. In those studies, additional primary care visits were associated with increased mammography receipt and rates of early stage breast cancer. Roetzheim and colleagues also found that mammography receipt only partially mediated the relationship between pre-diagnosis primary care and breast cancer mortality, suggesting primary care exerts effects independent of mammography [17]. This is consistent with the findings in our study population, where regular care and mammography adherence were correlated, but participants who lacked both forms of care had the most aggressive tumors at detection. But neither of the prior studies included oversampling for a racially diverse population (49% Black, age 45–74).

Screening adherence is correlated with other important social factors that affect diagnostic timeliness, under a multifactorial "cells-to-society" model of health equity where biology, social context, and macro-level structures interact to shape health outcomes [57, 58]. Prior studies have shown that socioeconomic disadvantage, smoking, and higher BMI are all associated with decreased mammography receipt [59–61]. However, our study also suggests that such differences may be further exacerbated by additional barriers to regular care, leading to a scenario wherein those most likely to benefit from mammography have higher chances of under-screening [62]. Additionally, such barriers to care have been shown to be linked to delays between detection and biopsy, another potential contributing factor to aggressive tumor presentation at diagnosis [63, 64].

Another strength of our analysis was exploration of geographic patterns of under-screening and lack of primary care. We found that one regional Area Health Education Center in the state of North Carolina, called Area L, had lower rates of care. This is one of the lowest-SES regions of the state that has experienced elevated cancer incidence and mortality (e.g., a documented colorectal cancer hotspot) [65, 66]. Future work will emphasize partnerships with local organizations to support mammography in medically underserved areas, as counties with fewer healthcare resources report greater frequency of late-stage breast cancer diagnoses [67]. Federally Qualified Health Centers (FQHCs) and Rural health centers (RHCs) are possible intervention targets, as these facilities provide a range of primary and specialty health services for underserved communities [68, 69]. Mobile screening units have also shown promise in expanding screening across diverse patient populations [70].

Limitations of our study include reliance on self-reported health care use; however, conversely healthcare utilization from administrative claims data also has limited sensitivity

[71]. Our measure of screening history was based on participant recall of the specific number of mammograms by decade and is likely subject to some misclassification error. A recent review found that self-reported mammography has high sensitivity (0.96), positive predictive value (0.80), and negative predictive value (0.86); but comparatively lower specificity (0.60) [72]. This means that over-estimation of screening receipt is our primary concern, but sensitivity analyses adjusting screening adherence in either direction induced little change in estimates. Also, women with an estimated rate of at least 0.5 mammograms/year made up 67% of our study population, nearly identical to most recent CDC estimates for biennial mammography receipt in the United States (68%) [73].

In summary, in a large racially diverse population of breast cancer survivors we found that inadequate access to screening and regular care are both important in diagnostic timeliness and tumor characteristics. Next steps include identifying individual- and community-level interventions that promote preventive care for Black women of screening age. Given geographic patterns, we believe policy and other health care system interventions that focus on underserved populations in North Carolina may be important next steps to achieve health equity in breast cancer outcomes.

Data availability To preserve patient confidentiality, Carolina Breast Cancer Study data are not publicly available but may be accessed after submission of a letter of intent and approval from the CBCS steering committee.

Declarations

Competing interests The authors declare no competing interests.

Disclosures The authors have no relevant financial or non-financial interests to disclose.

Ethical approval All study protocols were adherent to ethical standards of the institutional review board of the University of North Carolina at Chapel Hill, which approved the study.

Consent to participate Informed consent was obtained from all individual participants included in the Carolina Breast Cancer Study.

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