Underutilization of *BRCA1/2* testing to guide breast cancer treatment: Black and Hispanic women particularly at risk

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Purpose: Women with early-onset (age ≤40 years) breast cancer are at high risk of carrying deleterious mutations in the *BRCA1/2* genes; genetic assessment is thus recommended. Knowledge of *BRCA1/2* mutation status is useful in guiding treatment decisions. To date, there has been no national study of *BRCA1/2* testing among newly diagnosed women. **Methods:** We used administrative data (2004–2007) from a national sample of 14.4 million commercially insured patients to identify newly diagnosed, early-onset breast cancer cases among women aged 20–40 years (n = 1474). Cox models assessed *BRCA1/2* testing, adjusting for covariates and differential lengths of follow-up. **Results:** Overall, 30% of women aged 40 years or younger received *BRCA1/2* testing. In adjusted analyses, women of Jewish ethnicity were significantly more likely to be tested (hazard ratio = 2.83, 95% confidence interval: 1.52–5.28), whereas black women (hazard ratio = 0.34, 95% 0.18–0.64) and Hispanic women (hazard ratio = 0.52, 95% confidence interval: 0.33–0.81) were significantly less likely to be tested than non-Jewish white women. Those enrolled in a health maintenance organization (hazard ratio = 0.73, 95% confidence interval: 0.54–0.99) were significantly less likely to receive *BRCA1/2* testing than those point of service insurance plans. Testing rates increased sharply for women diagnosed in 2007 compared with 2004. **Conclusions:** In this national sample of patients with newly diagnosed breast cancer at high risk for *BRCA1/2* mutations, genetic assessment was low, with marked racial differences in testing. ***Genet Med* 2011:13(4):349–355.**

Key Words: *breast cancer, BRCA1/2, race, ethnicity*

Little is known about the diffusion and appropriate use of established genetic tests in the US health care system. Cancer genetics is one of the most developed areas of clinical genetics. Testing for *BRCA1* and *BRCA2* (*BRCA1/2*) mutations to assess risk of hereditary breast and ovarian cancer (HBOC) is among the most established genetic tests in clinical use.[1–3] Guidelines and commercial testing for *BRCA1/2* mutations have been available for more than a decade,[4] and most health insurers now reimburse at least partially for these tests in individuals at high risk for mutations.[5] National guidelines recommend that women diagnosed with early-onset breast cancer receive *BRCA1/2* testing to guide treatment decisions.[6] Among patients newly diagnosed with cancer, a positive test result will often prompt more aggressive surgical treatment (e.g., bilateral salpingo oophorectomy or prophylactic contralateral mastectomy) with the goal of minimizing the potential for second primary cancers.[3,7,8] A positive test result may also prompt consideration of *BRCA1/2* testing among at-risk relatives of the patient with cancer, so that those testing positive can benefit from more aggressive prevention and screening.[3]

Despite advances in testing criteria and knowledge about treatment strategies for mutation carriers, studies suggest that few women at high risk of hereditary breast cancer are offered genetic testing.[9] High-risk black women are less likely to be counseled or tested than high-risk white women,[10,11] mirroring racial disparities found in other aspects of cancer care and outcomes.[12,13] Among patients with newly diagnosed breast cancer, studies have examined the use of *BRCA1/2* testing only in the context of site-specific patient populations.[11,14] We are aware of no national study that assesses *BRCA1/2* testing among patients with early-onset breast cancer and the extent to which patterns of testing reflect national guidelines. This study addresses this important gap in the literature.

Specifically, we evaluated the use of testing for *BRCA1/2* mutations in a large, national sample of patients with newly diagnosed breast cancer aged 20–40 years using medical claims and demographic data from a large commercially insured population representing more than 14.4 million covered lives in the United States. We focused on women with early-onset breast cancer because this subpopulation is indicated for *BRCA1/2* testing according to National Cancer Center Network (NCCN) guidelines, and we can reliably identify this subset of women in claims data. We assessed rates of *BRCA1/2* testing in this group, determined whether minority and low-income women were less likely to receive testing, and tracked the diffusion of testing during the 2004–2007 period.

MATERIALS AND METHODS

Data and case definition

We analyzed medical claims and administrative information from a database of privately insured individuals residing in all 50 states and the District of Columbia. The database, covering January 2004 to May 2007, included approximately 14.4 million members annually. To identify patients with incident breast cancer, we first selected patients with a primary International

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Classification of Diseases, 9th edition, diagnosis code of female breast cancer (174.x) or ductal carcinoma in situ (233.0) during the study period. New cancer cases were defined as those with a primary diagnosis of breast cancer attached to surgical removal of the cancer. Removal was identified using Current Procedural Terminology, 4th edition, codes and International Classification of Diseases, 9th edition, procedure codes (Appendix, Supplemental Digital Content 1, http://links.lww.com/GIM/A145). Second, if a surgery claim was absent, a biopsy claim was considered evidence of a new breast cancer case if it was followed up within 6 months by ≥4 dates of service with radiation or chemotherapy treatment that were assigned a primary diagnosis code of breast cancer. Third, lumpectomy or mastectomy without an accompanying primary diagnosis code of breast cancer was assumed to be evidence of incident breast cancer if it was followed up within 6 months by ≥4 dates of services with claims for radiation or chemotherapy treatments assigned a primary diagnosis code of breast cancer. Our analysis was further restricted to patients aged 20–40 years. We required that patients have a minimum of 3-month continuous enrollment immediately before their initial treatment for cancer to confirm that we were capturing the initial diagnosis date. Those with claims containing codes for a personal history of breast cancer before the first observed date of treatment were also excluded from our sample of incident cases. Although the stringent criteria used to identify incident cases may have excluded some new breast cancer cases, we intentionally used a conservative approach as our goal was to assess adherence to national guidelines.

Our dependent variable was having a paid claim for *BRCA1/2* testing. Tests for mutations in these genes were identified using Healthcare Common Procedure Coding System codes specific to those tests. Healthcare Common Procedure Coding System codes are preferred by Myriad Genetics, the vendor that currently performs nearly all testing for *BRCA1/2* mutations.

Independent variables in our analyses included patient demographic data (age, race/ethnicity, and household income); insurance product (health maintenance organization [HMO], preferred provider organization, point of service, and exclusive provider organization); contextual data (average educational attainment at the Census block level, Census region, and year of diagnosis); and clinical characteristics (type of treatment received, additional cancer diagnoses, and family history of breast or ovarian cancer). Table 2 contains the specific categories included for each of these variables. Race/ethnicity was assigned based on imputation by a commercial firm under contract to the insurer using name recognition algorithms (incorporating first, middle, and last names) and Census data specific to individuals' geographic locations.[15] The imputation method used has been shown in previous studies to have moderate sensitivity (48%), excellent specificity (97%), and moderate positive predictive value (71%) for the purpose of identifying black patients with cancer in particular.[16] The characteristics of imputed Jewish ethnicity have not been assessed, but the imputation does identify 2% of the study sample as having Jewish ancestry, which is similar to national estimates.[17] We also test whether our results are sensitive to reclassifying all those identified as Jewish to non-Jewish white. Individuals for whom the algorithm was unable to impute an ethnicity and individuals for whom ethnicity was not imputed (e.g., because they were added to the dataset after the imputation had been performed) were combined into the "other/unknown" category. Household income was also imputed and validated by a commercial vendor[18] under contract to the insurer, based on income for a nationally representative sample of 150,000 households, consumer survey data, and ZIP code level data from the Internal Revenue Service. Education level associated with patients' Census block was coded as unknown when patients lacked data on Census block of residence. Clinical characteristics were determined based on diagnosis, procedure, and revenue codes (Appendix, Supplemental Digital Content 1, http://links.lww.com/GIM/A145). Although family history is likely to be underreported in claims data, it is likely to be accurate when reported. We included family history codes as a potential predictor of genetic testing only when the code occurred ≥30 days before a genetic test claim, thereby minimizing spurious correlations that may occur when family history coding is used to justify genetic testing.

The 2004 NCCN guidelines for HBOC risk assessment[19] are representative of the knowledge base available to clinicians during our study period. These guidelines detail various criteria indicating high risk of hereditary cancer and, thus, appropriateness for genetic testing. For patients with breast cancer, age ≤40 years, Ashkenazi Jewish ethnicity, diagnosis of ovarian cancer, and family history of breast or ovarian cancer indicate high HBOC risk. Among these criteria, age is most reliably measured in administrative data. We, therefore, conducted our analysis including only patients with newly diagnosed "early-onset" breast cancer (≤40 years), all of whom should be considered for genetic assessment according to the NCCN guidelines.

Statistical analysis

We used multivariate Cox proportional hazards models, assessing the time from first cancer diagnosis to receipt of a genetic test, to assess the likelihood of receiving genetic testing at any point in time after cancer diagnosis as a function of patient characteristics, while accounting for the different durations of follow-up observation that were possible depending on how long a patient's treatment lasted or when she was first observed in the data. Time of initial breast cancer diagnosis was defined as the earliest primary diagnosis of breast cancer coded within 3 months before the first date of breast cancer treatment. The Cox models allowed us to assess trends in utilization over time and identify patient characteristics associated with testing. Earlier research found different effects of race on testing when testing occurs in the first year after diagnosis compared with when it occurs beyond that point.[11] We estimated one model truncating follow-up at a maximum of 1 year and another in which follow-up was not restricted. The Cox models necessarily

Table 1 Application of exclusion criteria to identify new patients with cancer

Criterion	No. remaining after application of criterion breast cancer
Applicable breast cancer diagnosis and surgical treatment	41,548
Females	41,155
Age, 20–64 yr	32,978
≥3 Months enrollment before first treatment date	22,145
No personal history code before first treatment date	14,348
No missing data for multivariate analysis	14,235
Age, 20–40 yr	1,474

Table 2 Population characteristics and use of genetic tests

Characteristics	Population, *N* (%)	Had *BRCA1/2* test, *N* (%)
Overall	1,474 (100)	446 (30)
Race/ethnicity		
White (non-Jewish)	808 (55)	271 (34)
Black	82 (6)	10 (12)
Hispanic	116 (8)	21 (18)
Asian	56 (4)	15 (27)
Jewish	32 (2)	18 (56)
Other/unknown	380 (26)	111 (29)
Household income		
$0–29,999	53 (4)	11 (21)
$30,000–49,999	194 (13)	48 (25)
$50,000–99,999	571 (39)	173 (30)
$100,000–149,999	234 (16)	94 (40)
≥$150,000	38 (3)	17 (45)
Unknown	384 (26)	103 (27)
Education		
≤High school	400 (27)	97 (24)
≥College	802 (54)	272 (34)
Unknown	272 (18)	77 (28)
Region		
Northeast	199 (14)	52 (26)
South	644 (44)	211 (33)
Midwest	424 (29)	111 (26)
West	207 (14)	72 (35)
Provider type		
Exclusive provider organization	207 (14)	73 (35)
Health maintenance organization	250 (17)	53 (21)
Point of service	851 (58)	278 (33)
Preferred provider organization	166 (11)	42 (25)
Family history of breast/ovarian cancer		
No	1,188 (81)	362 (30)
Yes	286 (19)	84 (29)
Ovarian cancer diagnosis		
No	1,468 (99.6)	445 (30)
Yes	6 (0.4)	1 (17)
Breast conserving surgery		
No	521 (35)	169 (32)
Yes	953 (65)	277 (29)
Unilateral mastectomy		
No	1,049 (71)	302 (29)
Yes	425 (29)	144 (34)
Bilateral mastectomy		
No	1,425 (97)	434 (30)
Yes	49 (3)	12 (24)
Chemotherapy		
No	468 (32)	96 (21)
Yes	1,006 (68)	350 (35)
Radiation		
No	746 (51)	190 (25)
Yes	728 (49)	256 (35)
Trastuzumab therapy		
No	1,350 (92)	403 (30)
Yes	124 (8)	43 (10)
Hormone therapy		
No	858 (58)	218 (25)
Yes	616 (42)	228 (37)
Year		
2004	390 (26)	108 (28)
2005	450 (31)	121 (27)
2006	481 (33)	172 (36)
2007	153 (10)	45 (29)

excluded a small number of patients ($n = 11$) for whom we observed genetic testing before initial diagnosis.

Because the study used only deidentified data, it was deemed exempt from review by the Partners Health Care Institutional Review Board.

RESULTS

After applying stringent exclusion criteria, we identified a sample of 1,474 newly diagnosed early-onset breast cancer cases (Table 1). Six percent of patients were black, 8% Hispanic, 4% Asian, 2% Jewish, 55% non-Jewish white, and 26% "other or unknown" race/ethnicity (Table 2). Seventeen percent had family incomes below $50,000/year. Only 30% ($n = 446$) of our study sample was tested for *BRCA1/2* mutations. There was substantial variation in testing rates by patient characteristics absent of adjustment for confounders or differential durations of observation. Fourteen percent of those tested underwent testing before their treatment. The median time from diagnosis to testing was 4 months, and 91% were tested within 1 year of diagnosis (Fig. 1).

Our primary findings relate to the multivariate model with unrestricted follow-up (Table 3). Our model truncated at 1-year follow-up gave results that were nearly indistinguishable from the unrestricted model, so we only report the latter. We found a

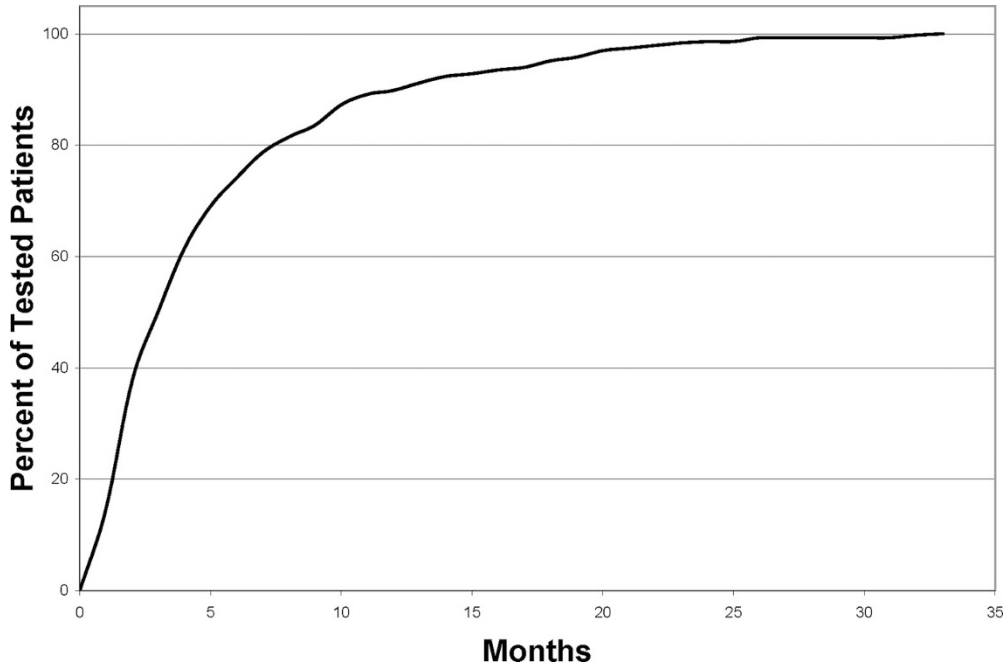

Fig. 1. Cumulative distribution of time from diagnosis to genetic testing for patients receiving testing.

number of important predictors of *BRCA1/2* testing among this cohort of newly diagnosed women. As one would expect, women of Jewish ethnicity, a key indicator of high risk for *BRCA1/2* mutations, were approximately three times as likely to receive testing compared with non-Jewish white women (hazard ratio [HR]: 2.83, 95% confidence interval [CI]: 1.52–5.28). Although a contemporaneous diagnosis of ovarian cancer would also warrant *BRCA1/2* testing, there were very few such diagnoses in the study sample, and we did not find a significant association between ovarian cancer diagnosis and *BRCA1/2* testing.

Controlling for other risk factors and all other covariates, black and Hispanic women were significantly less likely to receive *BRCA1/2* testing compared with non-Jewish white women (HR: 0.34, 95% CI: 0.18–0.64 and HR: 0.52, 95% CI: 0.33–0.81, respectively). There was a monotonically increasing likelihood of testing as a function of family income, although these associations were not statistically significant. However, when income was coded as an ordinal variable, a statistically significant association emerged, where women with family incomes >$150,000/year were 1.99 times as likely to be tested as women with incomes <$30,000/year (95% CI: 1.10–28.51; results not shown).

Several other factors were also significantly associated with the probability of testing. Patients who received chemotherapy, radiation therapy, or hormone therapy were more likely to receive testing than those not receiving those therapies (HR: 1.72, 95% CI: 1.36–2.18; HR: 1.24, 95% CI: 1.01–1.52; and HR: 1.29, 95% CI: 1.06–1.58, respectively). Women covered by an HMO insurance product were less likely to be tested than those with a point of service product (HR: 0.73, 95% CI: 0.54–0.99). Those living in the south were more likely to be tested than patients in the northeast (HR: 1.46, 95% CI: 1.07–2.00). After adjusting for covariates, the likelihood of testing increased consistently and substantially during the study period, with women diagnosed in 2007 3.79 times as likely to be tested as those diagnosed in 2004 (95% CI: 2.59–5.55).

We conducted a sensitivity analysis regarding the potential for bias in measuring differences between blacks or Hispanics and non-Jewish whites due to the misclassification of Jewish women as non-Jewish white women. If Jewish women more likely to be tested were misclassified as non-Jewish white women, that would increase the difference between non-Jewish whites and groups less likely to be tested. We intentionally reclassified the 32 women in the study identified as Jewish as non-Jewish white and recalculated the HRs. The new HRs (not reported) were nearly identical to those reported in Table 3). This suggests that there would have to be an implausibly high degree of misclassification to drive the differences we calculate between non-Jewish white women and black and Hispanic women.

DISCUSSION

Overview

Commercial testing for *BRCA1/2* mutations and clinical guidelines outlining when and how these tests can be useful to guide cancer care have been available for over a decade, but outside a handful of site-specific studies, very little is known about the use of these tests to guide cancer treatment. This is the first study, to our knowledge, assessing the rate of *BRCA1/2* testing among a group of patients with high-risk breast cancer in a large national sample. In this population of commercially insured patients with newly diagnosed early-onset breast cancer, we found low rates of testing even though such patients are all considered appropriate candidates for *BRCA1/2* testing according to national guidelines.

Our finding that only 30% of patients with newly diagnosed early-onset breast cancer received *BRCA1/2* testing is substantially lower than rates reported in other more specialized populations. A study of patients with breast cancer seen between 1998 and 2007 in the University of North Carolina (UNC) Cancer Genetics Clinic, for example, found that 69% of patients

Table 3 Proportional hazard models of the probability of *BRCA1/2* testing[a]

Characteristics	HR (95% CI)
Race/ethnicity	
White	1.0
Black	**0.34 (0.18–0.64)**
Hispanic	**0.52 (0.33–0.81)**
Asian	0.65 (0.38–1.12)
Jewish	**2.83 (1.52–5.28)**
Other/unknown	0.90 (0.65–1.23)
Household income	
<$30,000	1.0
$30,000–49,999	1.31 (0.67–2.56)
$50,000–99,999	1.41 (0.75–2.69)
$100,000–149,999	1.77 (0.90–3.48)
$150,000+	2.02 (0.91–4.49)
Unknown	1.15 (0.59–2.22)
Education	
≤High school	1.0
≥College	1.18 (0.89–1.55)
Unknown	1.56 (0.95–2.55)
Region	
Northeast	1.0
South	**1.46 (1.07–2.00)**
Midwest	1.03 (0.73–1.45)
West	1.31 (0.91–1.89)
Provider type	
Point of service	1.0
Exclusive provider organization	1.09 (0.84–1.42)
Health maintenance organization	**0.73 (0.54–0.99)**
Preferred provider organization	0.86 (0.62–1.19)
Family history of breast or ovarian cancer, yes (vs. no)	0.85 (0.66–1.08)
Ovarian cancer diagnosis, yes (vs. no)	0.48 (0.07–3.59)
Breast conserving surgery, yes (vs. no)	1.07 (0.60–1.88)
Unilateral mastectomy, yes (vs. no)	1.22 (0.69–2.17)
Bilateral mastectomy, yes (vs. no)	1.00 (0.45–2.21)
Chemotherapy, yes (vs. no)	**1.72 (1.36–2.18)**
Radiation, yes (vs. no)	**1.24 (1.01–1.52)**
Trastuzumab, yes (vs. no)	0.88 (0.64–1.22)
Hormone therapy, yes (vs. no)	**1.29 (1.06–1.58)**
Year of diagnosis	
2004	1.0
2005	0.99 (0.75–1.30)
2006	**2.04 (1.58–2.64)**
2007	**3.79 (2.59–5.55)**

Bolded text indicates significance ($P < 0.05$).
[a]Follow-up time for this model is not restricted.

with at least a 5% risk of carrying a *BRCA1/2* mutation according to the BRCAPro model received *BRCA1/2* testing.[11] A separate study of patients with newly diagnosed breast cancer at the Lombardi Comprehensive Cancer Center of Georgetown University in Washington, DC, found that among patients determined to have a 10% prior probability of *BRCA1/2* mutations (also based on BRCAPro), 76% underwent testing. These earlier studies are distinct from ours in that they report testing rates conditional on women receiving advice to undergo testing. Our analysis measures the proportion of women who actually got tested and does not assume that all women were offered testing. These prior studies were also conducted in large academic medical centers, whereas ours assesses routine clinical practice in diverse national clinical settings. As such, it is more reflective of the extent to which genetic testing has become integrated into clinical oncology as a tool for guiding treatment decisions nationally. Our results suggest that guideline-indicated *BRCA1/2* genetic assessment among women with breast cancer may be occurring less frequently that previously realized.

Furthermore, few women who are tested do so before their initial breast cancer treatment when results might inform initial treatment decisions, for example, whether to undergo prophylactic contralateral mastectomy or not. Without access to testing results, we were unable to determine whether those who got pretreatment testing used the results to guide their initial treatment decisions. Those who were tested after treatment may have done so with an eye toward future prophylactic care (e.g., bilateral salpingo oophorectomy) or informing potentially at-risk relatives.

There are many possible reasons for the low rates of testing we observe in this study, arising anywhere along a continuum of care from breast cancer diagnosis to the ultimate action taken with respect to *BRCA1/2* testing. Clinicians must be aware of and understand the latest evidence-based guidelines for diagnosis and care; collect and interpret family and clinical history information from the patient; and discuss possible testing with the patient and/or refer the patient for genetic counseling. There must be resources available from an insurer or the patient to pay for the test. Finally, the patient must decide to proceed with the test. Factors at any point along this continuum—at the health system, provider, or patient level—will affect *BRCA1/2* testing rates.

The UNC and Georgetown studies found relatively high rates of testing conditional on its offer (particularly when restricting their analyses to the year after diagnosis),[11,14] suggesting provider or systemic barriers are important contributors to the low utilization we observe in this study.[20] Physician knowledge of and compliance with practice guidelines are generally low, which may result in too few recommendations for testing.[21] System characteristics may also impede testing. Genetic counseling is a strongly recommended component of the genetic testing process,[1] and thus *BRCA1/2* testing typically requires an additional appointment for the patient. This provides another opportunity for women to be lost to follow-up. The short supply of genetic counselors has also been a concern, although it is not known whether patients are seeking and failing to find genetic counselors.[22] Our finding that HMO patients are less likely to be tested suggests that administrative barriers such as prior authorization requirements or the use of restricted provider lists may also play a role in low utilization.

Beyond barriers affecting access to testing, some patients may have refused genetic testing when offered due to lower knowledge of hereditary cancer testing,[23–26] personal preferences or beliefs,[27] or fears that genetic risk information may be used by an insurer or employer to discriminate against

them.[28–30] Differences in testing rates by race (see later) suggest that for blacks this may be of particular concern,[31] reflecting historic injustices in medical research and genetics.[32–34] Going forward, some of these fears may be allayed by the 2008 Genetic Information Nondiscrimination Act.[35]

BRCA1/2 testing and underserved populations

We observed significantly lower rates of *BRCA1/2* testing for black, Hispanic, and low-income women compared with others being served in the same large commercial health plans. It is these underserved populations that experience poorer treatment and higher mortality rates for breast cancer.[13]

Our finding of lower testing rates among black women mirrors the differences in genetic counseling and testing observed in other studies. Armstrong et al.[10] used a case-control design to study genetic counseling rates for women with a family history of breast and ovarian cancer, but without a cancer diagnosis themselves, in a large metropolitan health system and found that black women had one fifth the odds of pursuing genetic counseling compared with white women. It should be noted that these women were at risk of developing breast and ovarian cancer in the future, which has different implications for discrimination than testing among women with incident breast cancer where a key purpose of testing is tailoring treatment. A study of patients with ovarian cancer seen at M.D. Anderson Cancer Center who were at high risk of *BRCA1/2* mutations found that compared with white women, black women had a 75% lower odds of receiving offers of or referrals for genetic counseling, suggesting provider behavior is an important barrier to testing.[20] The authors found no significant difference between white and Hispanic women. The UNC and Georgetown studies involved patients with breast cancer specifically. When focusing on testing in the year after breast cancer diagnosis, the UNC study found that 66% of blacks received *BRCA1/2* testing compared with 72% of whites ($P = 0.27$), and the Georgetown study found that 78% of nonwhites were tested compared with 85% of whites ($P = 0.66$). However, when restricting their analysis to women who were tested more than 1 year after diagnosis, the UNC study found black patients with breast cancer had less than half the odds of undergoing *BRCA1/2* testing as white patients, despite similar access to counseling and care. Our findings are notable for demonstrating significantly lower rates of testing for blacks regardless of whether the analysis focused on the first year after diagnosis or not.

Our study is the first to report on *BRCA1/2* testing rates among Hispanic patients with breast cancer compared with whites. However, others have noted seemingly low rates of testing among Hispanic women, despite findings that the prevalence of *BRCA1/2* mutations among Hispanics is similar to other groups.[36–38] Future studies are needed to confirm our results and explore how *BRCA1/2* testing is affected by the relationship between provider characteristics among those serving Hispanic women with breast cancer and the preferences, beliefs, and barriers experienced by various Hispanic communities.

How might these data inform efforts to reduce disparities in *BRCA1/2* testing? Care for black patients, in particular, is generally concentrated among a relatively small number of inpatient and outpatient providers, and these providers may face special challenges in providing high-quality care for their patients.[39,40] Hospitals serving more minority patients have poorer outcomes for patients with breast cancer[12] and lower quality of care, generally.[41] A national survey of primary care physicians found that minority-serving physicians were significantly less likely to have ever ordered genetic testing to assess breast cancer risk.[42] The extent to which care for minority patients with cancer is concentrated among relatively few oncologists is unknown. Identifying that subset of oncologists who treat the majority of black and Latino women with breast cancer may prove a useful strategy for targeting provider and patient education and outreach efforts, as well as targeting additional resources for service delivery infrastructure.

Low-income women are also less apt to receive *BRCA1/2* testing, even after controlling for race/ethnicity, insurance coverage, and average levels of educational attainment within one's neighborhood. Previous studies have considered income as a predictor of genetic testing for hereditary cancers, but their findings were either borderline[43] or insignificant.[10] Although we use imputed income data, the monotonically increasing likelihood of *BRCA1/2* testing we observe across five income categories is an indication of an income effect. The role of genetic counseling in the *BRCA1/2* testing process may prove a greater burden to low-income women, who are more likely to hold less flexible jobs and rely on public transportation, and thus may have more difficulty getting to medical appointments. Even modest cost-sharing requirements for testing may prove sufficiently burdensome to deter testing among low-income women. Our family income variable may also reflect education above and beyond the area-level measures of education we used and, thus, reflect education-related differences in understanding of genetics and/or willingness to undergo genetic testing. Further investigation of the effect of socioeconomic status on test uptake is warranted.

Limitations and conclusions

The strength of analyses based on administrative data is the ability to reliably capture specific trends and patterns in utilization over a large number of patients.[44] However, there are limitations of our study that deserve mention. Our findings represent the experience of commercially insured patients with uneven national geographic distribution and may not be generalizable to the United States as a whole. Some patients may have undergone genetic testing before our study period, and others may have paid for testing out of pocket, rendering those tests invisible in our analyses. Certain variables may have been misspecified due to incomplete use or documentation in administrative data (e.g., family history), imputation processes (e.g., race/ethnicity and income), or incomplete data (addresses needed to compute neighborhood characteristics, such as average education level). With respect to the imputed race/ethnicity variable, additional research using validated, self-reported race/ethnicity is needed to further establish our findings. We believe, however, that potential miscoding is likely concentrated in the reference group (whites), which is large, and would therefore most likely bias results toward the null hypothesis of no association. Despite the limitations of our race variable, the magnitude of our results strongly suggest that disparities observed elsewhere in cancer care also exist in the provision of *BRCA1/2* testing, and this warrants further investigation. Notwithstanding these limitations, this study provides the first national data on utilization of genetic testing to guide cancer treatment among a large national sample of patients with newly diagnosed breast cancer, documents low rates of testing among patients identified as appropriate for genetic assessment by national guidelines, and points to critical needs for further research investigating racial and socioeconomic differences in utilization of *BRCA1/2* testing.

Despite calls for greater awareness on the part of patients and physicians,[29] the use of recommended genetic tests to assess risk of hereditary cancer remains low, even among younger patients with cancer at high risk of mutations. Nevertheless, testing rates are rising. Efforts to educate providers about the benefits of genetic assessment[45] and recent legislative protec-

tions against genetic discrimination[35] may further stimulate additional usage in the future. Disparities in *BRCA1/2* testing rates may lead to or compound disparities in cancer treatment and cancer outcomes. Intensified efforts are needed to ensure that poor and minority patients have access to clinical innovations, such as genetic assessment, shown to provide clinical value in tailoring cancer treatment and improving long-term outcomes. Low rates of *BRCA1/2* testing among patients who would realize clinical benefit from knowing their mutation status represent a lost opportunity to tailor women's individual treatment plans and maximally reduce risk of recurrence.

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