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Arthi Reddy Date

Mammography Screening Delays in Metro-Atlanta by Race (White/Black), Age, Socioeconomic Status, Insurance, and Distance to Facility

By

Arthi Reddy
Master of Public Health

Epidemiology

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Lauren E. McCullough, PhD, MSPH
Committee Chair

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By

Arthi Reddy

B.S.
University of Alabama, Birmingham
2017

Thesis Committee Chair: Lauren E. McCullough, PhD, MSPH

An abstract of
A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University
in partial fulfillment of the requirements for the degree of
Master of Public Health
in Epidemiology
2020

Abstract

Mammography Screening Delays in Metro-Atlanta by Race (White/Black), Age, Socioeconomic Status, Insurance, and Distance to Facility

By Arthi Reddy

Breast cancer survival prognosis is heavily influenced by early detection through mammography screening. In 2019, there were an estimated 268,600 newly diagnosed cases of invasive breast cancer, which represents 15.2% of all new cancer cases, along with 62,930 new cases of non-invasive (*in situ*) breast cancer. Since the advent of mammography screening, 5-year relative survival rates have improved to 99% for localized cancer, 86% for regional cancer, and 27% for distant cancer. However, mammogram screening delays in diagnosis can prevent the early detection of breast cancer. Using data from six hospitals in the metro-Atlanta region within the state of Georgia, we aimed to understand what factors (e.g., race, age, socio-economic status [SES], insurance, distance) associate with delays in screening among non-Hispanic White (NHW) and non-Hispanic Black (NHB) ultimately diagnosed with breast cancer between 2010-2014 (n=806). Results showed that NHB women were more likely to face delays in diagnosis compared to NHW women and SES-related factors were associated with diagnostic delays. The number of days in delays were, overall, more than those reported for the US populations and our findings are different from those of equal-access institutions that showed no such racial differences. We hypothesize that African-American race is a surrogate to SES factors and further research is needed to suggest remedial measures to overcome these racial differences.

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Acknowledgements

I would like to first thank Dr. Lauren McCullough for being my thesis advisor and mentor since the start of my time at Rollins. She shared her research with me and guided me through the process of writing my thesis as well as giving me opportunities to grow. Dr. McCullough gave me valuable advice that I will continue to follow as I become a public health professional and use public health in my future career. Without her, I would not be graduating with a Master's in Public Health. I will always admire your knowledge in cancer epidemiology and willingness to share it with others.

Next, I would like to thank Lindsay Collins, Dr. McCullough's doctoral student. You have been more helpful than I could ever imagine someone being. I cannot thank you enough for answering my endless questions. You were always an email away, and I am eternally grateful for your guidance through the thesis process.

Finally, I would like to thank my family for their support and encouragement through this process. Thank you for pushing me every day to continue learning and never give up. I would not be graduating with a Master's in Public Health without the endless support from my family. Thank you for continuing to motivate me as I finish and publish my thesis.

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Background

In the US, breast cancer is the most commonly diagnosed non-melanoma cancer among women regardless of a woman's race and/or ethnicity[1]. In 2019, there were an estimated 268,600 newly diagnosed cases of invasive breast cancer, which represents 15.2% of all new cancer cases, along with 62,930 new cases of non-invasive (*in situ*) breast cancer[2]. The overall incidence rate of female breast cancer 2012-2016 was 127.5 per 100,000 women per year [3]. Non-Hispanic Whites [NHW] had 130.8 new cases per 100,000 women at risk. Non-Hispanic Blacks [NHB] had the next highest at 126.7 cases[4].

In Georgia, breast cancer is the most common type of cancer diagnosed among women and is the second-leading cause of cancer deaths among Georgia women, after lung cancer [5]. NHB and Hispanic women in Georgia have breast cancer incidence rates higher than the U.S rates for those groups, while NHW women in Georgia have lower rates than in among NHW women in the U.S. Mortality rates for both black women and white women are lower in Georgia than in the overall U.S according to data from 2007-2011[6]. The four public health districts in metro-Atlanta, Cobb/Douglas health districts, Fulton Health District, East Metro District, and Dekalb Health district have significantly higher breast cancer incidence rates than the rest of the state.

Mortality rates for women with breast cancer is 42% greater among NHB women than NHW women [7]. This is due partly to the fact that NHB women are diagnosed at later stages, earlier ages, have less access to quality care, and have lower socio-economic status [SES] [8]. Non-Hispanic Black women are, in part, diagnosed at a later stage because they may have delays in screening[9]. Other biological and sociodemographic characteristics also come into play for the

later diagnosis[8]. Though the gap in incidence between white and black women is closing, the mortality gap remains pronounced [8]. NHW women are more likely to develop breast cancer than NHB women from the ages of 65-84, and NHB are more likely to develop breast cancer than NHW women under the age of 40[10]. The five-year relative survival is 89% among NHW women, compared to 75% among NHB counterparts[11].

Breast cancer survival varies by the stage at diagnosis[12]. Stage four cancers are most often the distantly spread cancers with the lowest 5-year survival rates at diagnosis[13]. According to the American Cancer Society, between 2012-2016 the frequency of local stage at diagnosis was 64%, regional was 27%, and distant was 6%[14]. However, when stratified by race NHW were more likely to be diagnosed with early stage breast cancer than NHB counterparts (64-66% vs. 56-60%)[14]. Data indicate that diagnostic delay appears to be an important determinant of stage at diagnosis in women with breast cancer and that it has an important influence on survival [15]. Because early treatment is one of the most important factors of breast cancer prognosis, a reduction in diagnostic delay and the completion of diagnostic procedures has the potential to improve overall survival [15]. Early detection is associated with decreased mortality; therefore, it is important to minimize delays in detection, diagnosis, and treatment while ensuring the completion of the diagnosis process[16].

Mammography screening has greatly increased the number of breast cancers detected before symptoms begin to show. Mammography randomized controlled trials have shown that population screening reduces mortality from breast cancer by a relative risk of 20%[17]. Mammograms detect tumors before they would be detectable by hand. Efficacy of mammogram screening is dependent on age and has shown to be most evident in women 50-69 years of age,

with less benefit outside of this age range [18]. Mammography, a population screening strategy, is aimed at detecting breast cancer at an early stage for effective treatment [17]. The diagnosis of breast cancer is based is based on three tests: clinical examination, imaging (usually mammography and/or ultrasonography) and needle biopsy [17]. A screening mammogram is performed in cases where there isn't any known problem[18]. This type of mammogram is used for annual exams as part of the check-up process. A diagnostic mammogram is performed after the screening mammogram when there is a known problem that requires careful evaluation[19]. Diagnostic mammograms provide more clear, visual images than screening mammograms, such as views from additional angles and compression, or enhanced, views[18]. If those results are indeterminate, a biopsy is recommended. A breast biopsy is a test that removes tissue or fluid from the suspicious area[20]. A biopsy is the only diagnostic procedure that can determine if the suspicious area is cancerous[21].

In the U.S., most abnormal mammography is followed up within three weeks of time. In breast cancer screening, up to 10% of screening mammography is abnormal, which means that these women are called back for diagnostic testing or a breast biopsy[22]. Currently, there is no consensus as to the appropriate timeline for follow-up after an abnormal mammography[22]. Waiting for results induces anxiety in women, which may make them less likely to continue getting screened[23]. However, the sooner the women receives instructions on how to follow-up, the better her outcome.

Many women face barriers to screening that prevent them from receiving a timely diagnosis. Among insured women, those under the age of 60, those with a health plan membership under five years, those with family income less than $40,000 a year, and those who

were obese had low mammography completion rates[24]. Younger women were more likely to not get mammograms because they were "too busy" and did not think their mammogram results were accurate. Uninsured populations often face obvious barriers, such as reduced access to healthcare, not having a primary care physician, and having to pay out-of-pocket for screening [24].

In this study, we sought to examine which characteristics are associated with screening delay and ultimately a delay in diagnosis. The ultimate goal of this work is to inform interventions that may facilitate earlier detection of breast cancer in vulnerable populations of women living in metro-Atlanta.

Methods

Sample Population

Data for this retrospective cohort study were obtained from six hospitals: Emory University Hospital; Emory University Hospital Midtown; The Emory Clinic; Emory St. Joseph's Breast Health Center; Emory St. Joseph's Mobile Mammography Unit; and Emory John's Creek Hospital. All of the 806 women in the study had confirmed breast cancer diagnoses. The initial screen dates and the diagnosis screen dates ranged from 2009-2014, and the biopsy screen dates ranged from 2010 -2014.

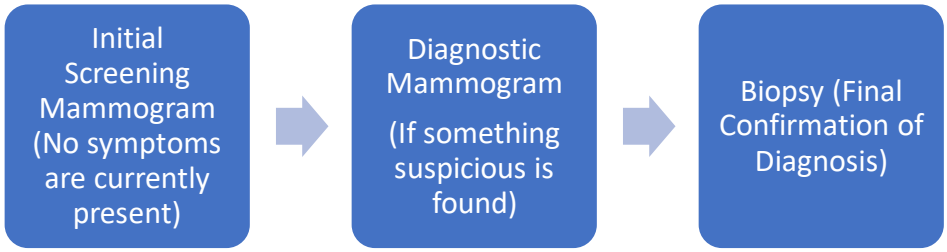
Exposure

The five exposure variables being measured for association with delay were race/ethnicity, SES, insurance, age, and distance to mammogram facility, as detailed below. For this study, women were categorized as NHW or NHB. We ascertained SES by abstracting median household income from the American Community Survey using a patient's recorded zip code at diagnosis and dividing median household incomes into four quartiles. The first quartile contained median household incomes ranging from $13,000 to $37,000, the second from $37,000 to $50,000, the third from $50,000 to $67,000, and the fourth quartile from $67,000 to $150,000. Insurance was categorized into the four following groups: private (Blue Cross, HMO, and PPO), Medicare, Medicaid, and self-pay. Geographical distance to facility for each patient was obtained by finding the distance between each patient's hospital zip code and their zip code of residence using a SAS macro [25]. The geographical distance to facility was subsequently categorized by dividing the distances into four quartiles (Q1=0 to 5.8 miles; Q2=5.8 to 10.8 miles; Q3=10.8 to 18.95 miles; Q4=18.95 to 199 miles). Age was categorized into four quartiles (Q1<55; Q2= 55-

65; Q3=66-75; Q4>75). These age ranges were categorized based on the current mammography screening guidelines and recommendations.

Outcome

The outcome variables being measured are diagnostic delay, biopsy delay, and total delay. The diagnostic delay is the number of days from the initial screening date to the diagnostic mammogram screening date. The biopsy delay is the number of days from the diagnostic screening date to the biopsy date. Total delay was found by summing the biopsy delay days and diagnostic delay days. The diagram below shows the order of diagnosis events.



In order to assess the odds of delay for logistic regression, we defined the number of days that would be considered appropriate to receive mammography results. As delay is not currently clinically defined, we decided appropriate times points for delay based on average delay days in clinical practice, both anecdotally and from literature that was reviewed. For diagnostic delay, anything greater than 30 days was recorded as a delay. For biopsy delay, anything greater than 15 days was recorded as a delay. For total delay, the number of days greater than 45 was considered to be a delay.

Covariates

Age was adjusted for in all of the models. Other adjustments were made based on the exposure-outcome association of interest informed by causal diagrams (Figures 1-5) and the literature.

Statistical Analyses

Our statistical approaches included descriptive statistics, linear regression (delay as a continuous variable) models, multivariable logistic (delay vs. non-delay) regression models, and quantile regression (to account for non-linearity of the exposure-outcome association). We report descriptive statistics (median, IQR) for each of the exposure variables. Next, we estimated the association between each exposure on delay (continuous and categorical) reporting mean difference and odds ratios (ORs) with corresponding 95% confidence intervals (95% CIs), respectively. Given that the distribution of the outcome variable (delay) is not normal, we used quantile regression to find the beta estimates at the 50% level.

Results

Descriptive data

The data set included a total of 806 women, compromising 403 NHW and 403 NHB women. NHBs consistently had greater delays days than NHWs. We also observed the most pronounced delays among women aged 65–75 years and women with earned income between $16,000 and $37,000 (Table 1). Women with Medicaid insurance faced the greatest number of delay days, as did women whole lived 5.8 to 10.8 miles from their testing center (Supplemental Table 2).

Quantile Regression

Quantile regression at the 50% level was used because the data was not linearly related. On average, NHB women experienced 15 (10.37,19.63) more total delay days from mammographic screening until biopsy compared to NHW women. Those in the age range from 65-75 experienced 3 (-5.98, 11.98) more total delay days compared to those under the age of 55. Those with a median income between $13,000 and $37,000 experienced 8 (0.90 ,15.10) more total delay days than those in quartile four whose median income ranges from $67,000 to $150,000. Women insured by Medicaid experienced 5 (-6.20, 16.20) more total delay days than those who had private insurance. Those who were a distance of 5.8 to 10.8 miles away from a screening facility experienced on average 8 (1.12,14.88) more total delay days than those who were under 5.8 miles away.

Logistic Regression

We estimated odds of delay by dividing delay into categories (Table 3). Among NHB women we observed a 2-fold increased odds of total delay compared to NHW women (OR=2.08

95%CI 1.55, 2.79). Across all categories, age was associated with total delay. Patients with income $13,000 to $37,000 were 24% more likely to experience delay compared to women with income $67,000 to $150,000 (95% CI: 0.79, 1.96). Similarly, we observed a 71% increased odds of total delay among women with Medicaid were (0.56, 5.29) compared to women with private insurance. We observed no relationship between distance to facility and delay.

Linear Regression

Linear regression is included in the appendix as Supplemental Table 2 because our data is not linearly related. On average, NHB women experienced 6.28 (-3.24, 15.8) more delay days than NHW women. Those aged 66-75 experienced the greatest number of total delay days of 4.67

(-16.25, 25.59). As socioeconomic status increased, the number of average delay days decreased. Those with Medicaid showed 29.34 (-10.04, 68.72) more number of total days compared to other insurances; this was much higher number of total delay days than the other insurance categories. The number of total delay days on average was lower for all distance categories compared to those who lived under 5.8 miles away from the facility. There was no general trend in the distance category.

Discussion

In summary, black women experienced a greater number of delays across the screening trajectory (diagnostic, biopsy, and total delay days). While age, SES, and distance to facility were associated with delay – the effects were less pronounced and largely imprecise.

Average delay times were higher in this data set from Metro-Atlanta than the rest of the United States. We calculated a mean diagnostic delay of 56 days and a median delay of 32.5 days for the sample population. This compares to an average diagnostic delay of 21-30 days from initial screening to diagnosis in several sample populations in community-based populations across the United States [26]. Results from a population-based US study were based on pooled data sent to the BCSC Statistical Coordinating Center (Seattle, Wash) from six registries in North Carolina, Western Washington State, New Hampshire, New Mexico, San Francisco, and Vermont. Women with a recommendation for additional screening had a median follow-up of 14 days and a median follow-up of 16 days for biopsy, which totals to 30 total diagnostic days.

In our analyses, we observed that NHB women were persistently more likely to experience a delay at each phase of the diagnostic work-up compared to NHW women. Our findings are similar to that of Gorin et al., who found that African-Americans experienced higher diagnostic delay than whites[27] . The study was a Medicare linked database for women aged 64 and older, in which more African-American women faced 1-2 months of diagnostic delay. In our study, age was associated with delay in both quantile and logistic regression analyses, while SES and distance had varying trends. The odds of delay increased as socioeconomic status

decreased for both univariate and multivariable analyses. A shorter distance to facility was also associated with less total delay days. Our data may suggest that race alone is not the cause of diagnostic delays; there may exist an interaction between race and SES that can explain our findings. We hypothesize that race is a surrogate indicator of other factors in diagnostic delays. This hypothesis is supported by Smith et al study [28]. Smith et al. found that time to diagnosis between the abnormal mammogram and the breast cancer diagnosis did not differ between African-Americans and whites in an equal access program for undeserved women 200% below the federal poverty line in South Carolina. Biologic differences, such as the higher ER-negative tumor mortality, however, showed diagnostic delay differences. This study's finding may be more applicable to our study of African-Americans in the Southeast, especially in areas such as Metro-Atlanta.

Kshama et. al similarly found no diagnostic delay for vulnerable low-income citizens regardless of race receiving breast cancer diagnosis at the Denver Health and Hospital Authority, which is an integrated, safety-net hospital system[26]. We were unable to separate data from community hospitals, suburban hospitals, safety-net hospitals [such as Grady] versus for-profit hospitals in our study. This may explain the differences in our finding versus that of Smith et al and Kshama et al. These studies suggest that programs and hospitals in different regions of the United States that are providing equal access care regardless of insurance and ability to pay are not showing a difference in diagnostic delay by race/ethnicity. Diagnostic delay is influenced by accessibility to care more so than biologic differences between races. There may be other covariates that need to be adjusted for that were not included in the data set to control for

possible confounding. This study is unique in that we are looking at delay in diagnosis, rather than delay in the treatment time.

One possible limitation of our study is the loss of information and heterogeneity that was created by the categorization of variables such as household income, age, and distance. This may also lead to a loss of generalizability across studies that use these same variables. We did not analyze our data in terms of not-for-profit versus for-profit hospitals which may also have influenced our findings, as each treats people of different demographics. Finally, selection bias may have been an issue, as all women in the study were diagnosed with breast cancer.

We conclude that race acts as a surrogate for other factors when we compare our results to those published in the literature. We would benefit from additional research with larger numbers of participants to uncover these complex relationships and ultimately suggest remedial measures.

Tables

Table 1. Demographic characteristics by screening delay characteristics (average BX Days, DX Days, and LOC Days) among 806 women who underwent breast cancer screening prior to a breast cancer diagnosis in the metropolitan Atlanta area (2010-2014).

Demographic Characteristics	Median DX Days		Median BX Days		Total Delay Days	
	Median	IQR	Median	IQR	Median	IQR
Race/Ethnicity						
White	16.5	8,32	6	2.11	25	14.49
Black	27	16,42	9	4.18	40.00	25,64
Age Category						
<55	21.5	14,40	6	2,12	33.5	20.5,57
55-65	21	13,38	6	2,15	30.5	19,56
65-75	23	13,41	7	3,14	36	19,63
>75	20	12,36	7	3,15	31	18,58
Socioeconomic Status						
Quartile 1($16,000-$37,000)	25.5	13,42	8	3,17	37	20,68
Quartile 2 ($37,000-$50,000)	25	14,38	8	4,18	36	21,59
Quartile 3 ($50,000-$67,000)	19	11,40	7	2,13	28.5	15,61
Quartile 4 ($67,000-$150.000)	20	11,32	6	2,13	29	18,51.5
Insurance Status						
Private (BLUE CROSS, HMO PPO)	22	13,39	7	2,14	32	19,60
MEDICARE	21	11,37	7	3,15	33	18,59
MEDICAID	27.5	14,47	13.5	7,47	42	29,84
Self-Pay	21	12,44	9	3,27	36	21,62
Geographical Distance to Screening Facilities (Miles)						
Range 1 (0-5.8)	21	12,40	6	2,15	30	17,60
Range 2 (5.8-10.8)	25.00	16,37	8.00	4,16	37	25,61
Range 3(10.8-18.95)	25.00	13,36	7.00	3,16	33.5	20,56
Range 4(18.95-199)	16.00	6,37	6	2,13	26	13,58

Table 2. Association between patient demographic characteristics and average screening delay among 806 white and black women diagnosed with breast cancer in Atlanta (2010-2014) using quantile regression at the 50% quantile multi-variable adjusted and age-adjusted

Demographic Characteristics		Median DX Days		Median BX Days		Median Total Delay Days	
		Age-adjusted β (95%CI)	Adjusted[a] β (95%CI)	Age-adjusted β (95%CI)	Adjusted[a] β (95%CI)	Age-adjusted β (95%CI)	Adjusted[a] β (95%CI)
Race/ Ethnicity							
	White	Ref	Ref	Ref	Ref	Ref	Ref
	Black	10.5 (7.98, 13.02)	10 (7.35, 12.65)	3 (1.66, 4.34)	3 (2.01, 3.99)	15 (10.37, 19.70)	15 (10.37, 19.63)
Age Category							
	<55	Ref	Ref	Ref	Ref	Ref	Ref
	55-65	0 (-6.06, 6.06)	-0.5 (-7.47, 6.47)	-2 (-11.10, 7.10)	0 (-2.69, 2.69)	-2.00 (-11.10, 7.10)	6.5 (-4.87, 17.87)
	66-75	2 (-3.99, 7.99)	1 (-4.12, 6.12)	3 (-5.98, 11.98)	-0.33 (-2.31, 1.64)	3.00 (-5.98, 11.98)	5.5 (-2.83, 13.83)
	>75	-1 (-6.88, 4.88)	1 (-3.61, 5.61)	-2 (-10.81, 6.81)	0 (-1.78, 1.78)	-2.00 (-10.81, 6.81)	7 (-0.48, 14.48)
Socioeconomic Status							
	Quartile 1 ($13,000-$37,000)	6 (2.02, 9.98)	0 (-3.59, 3.59)	8 (0.90, 15.10)	0 (-2.05, 2.05)	8 (0.90, 15.10)	0.5 (-7.05, 8.05)
	Quartile 2 ($37,000-$50,000)	4.5 (0.60, 8.40)	-1 (-4.50, 2.50	7 (0.036, 13.96)	0 (-2.00, 2.00)	7 (0.04, 13.96)	-2 (-9.38, 5.38)
	Quartile 3 ($50,000-$67,000)	-0.5 (-4.42, 3.42)	-1.67 (-4.99, 1.66)	0 (-7.00, 7.00)	0 (-1.90, 1.90)	0 (-7.00, 7.00)	-2.5 (-9.50, 4.50)

Quartile 4 ($67,000-$150.000)	Ref	Ref	Ref	Ref	Ref	Ref
Insurance Status						
Private (BLUE CROSS, HMO PPO)	Ref	Ref	Ref	Ref	Ref	Ref
MEDICAID	5 (-6.20, 16.20)	0.85 (-8.73, 10.44)	6 (-13.93, 25.93)	6 (0.84, 11.16)	6 (-13.93, 25.93)	9 (-9.10, 27.10)
MEDICARE	-1 (-5.20, 3.21)	-1.86 (-5.35, 1.63)	2 (-5.46, 9.46)	0 (-1.88, 1.88)	2 (-5.46, 9.46)	-2 (-8.55, 4.55)
Self-Pay	-1 (9.99, 7.99)	0 (-7.39, 7.39)	4 (-12.01, 20.01)	3 (-0.98, 6.98)	4 (-12.01, 20.01)	5 (-8.94, 18.94)
Geographical Distance to Screening Facilities (Miles)						
Range 1 (0-5.8)	Ref	Ref	Ref	Ref	Ref	Ref
Range 2 (5.8-10.8)	4.67 (0.53, 8.80)	0.27 (-3.34, 3.88)	2 (0.61, 3.39)	1.94 (-0.03, 3.92)	8 (1.12, 14.88)	4.06 (-2.22, 10.33)
Range 3(10.8-18.95)	5.33 (1.06, 9.61)	0.82 (-2.91, 4.55)	0.5 (-0.94, 1.94)	0.82 (-1.22, 2.86)	5 (-2.13, 12.13)	2.22 (-4.28, 8.73)
Range 4(18.95-199)	-5 (-9.34, -0.65)	-3.73 (-7.46, 0.01)	-1.5 (-3.12, 0.12)	-0.12 (-2.16, 1.92)	-5 (-12.24, 2.24)	-5.72 (-12.22, 0.78)

[a] Age adjusted for insurance and distance; SES adjusted for age and race; Insurance adjusted for age, race, and SES; Distance adjusted for age, race, SES and insurance

Table 3. Association between patient demographic characteristics and average screening delay among 806 white and black women diagnosed with breast cancer in Atlanta (2010-2014) multi-variable adjusted and age adjusted.

Demographic Characteristics	Average DX Days		Average BX Days		Average Total Delay Days	
	Age-adjusted OR (95%CI)	Adjusted[a] OR (95%CI)	Age-adjusted OR (95%CI)	Adjusted[a] OR (95%CI)	Age-adjusted OR (95%CI)	Adjusted[a] OR (95%CI)
Race/ Ethnicity						
White	Ref	Ref	Ref	Ref	Ref	Ref
Black	1.8 (1.32, 2.45)	1.83 (1.36, 2.47)	2.31 (1.63, 3.27)	2.46 (1.76, 3.43)	1.97 (1.45, 2.67)	2.08 (1.55, 2.79)
Age Category						
<55	Ref	Ref	Ref	Ref	Ref	Ref
55-65	1.13 (0.75, 1.70)	1.25 (0.66, 2.36)	1.21 (0.63, 2.32)	1.14 (0.58, 2.26)	1.20 (0.67, 2.15)	1.33 (0.71, 2.49)
66-75	1.08 (0.71, 1.66)	1.16 (0.58, 2.33)	1.06 (0.56, 2.04)	0.86 (0.43, 1.72	1.24 (0.70, 2.20)	1.24 (0.66, 2.32)
>75	0.83 (0.53, 1.29)	1.04 (0.59, 1.85)	1.21 (0.64, 2.29)	0.84 (0.40, 1.76)	1.10 (0.63, 1.94)	1.14 (0.58, 2.26)
Socioeconomic Status						
Quartile 1 ($13,000-$37,000)	2.07 (1.33, 3.21)	1.55 (0.98, 2.47)	1.91 (1.18, 3.09)	1.32 (0.79, 2.20)	1.78 (1.16, 2.73)	1.24 (0.79, 1.96)
Quartile 2 ($37,000-$50,000)	1.63 (1.05, 2.52)	1.3 (0.82, 2.07)	1.82 (1.13, 2.94)	1.21 (0.73, 2.03)	1.45 (0.95, 2.21)	1.03 (0.65, 1.62)

Quartile 3 ($50,000-$67,000)	1.39 (0.89, 2.17)	1.19 (0.76, 1.87)	1.39 (0.85, 2.27)	1.11 (0.67, 1.84)	1.25 (0.8, 1.92)	1.02 (0.66, 1.58)
Quartile 4 ($67,000-$150.000)	Ref	Ref	Ref	Ref	Ref	Ref
Insurance Status						
Private (BLUE CROSS, HMO PPO)	Ref	Ref	Ref	Ref	Ref	Ref
MEDICARE	1.11 (0.36, 3.40)	0.89 (0.58, 1.37)	2.46 (0.83, 7.25)	1.11 (0.67, 1.84)	1.87 (0.64, 5.48)	0.9 (0.59, 1.37)
MEDICAID	0.93 (0.61, 1.43)	1 (0.32, 3.17)	1.14 (0.82, 1.60)	2.32 (0.74, 7.24)	0.95 (0.63, 1.44)	1.71 (0.56, 5.29)
Self-Pay	0.74 (0.28, 1.95	0.65 (0.25, 1.69)	2.11 (0.88, 5.01)	2.13 (0.87, 5.17)	1.54 (0.65, 3.66)	1.33 (0.56, 3.15)
Geographical Distance to Screening Facilities (Miles)						
Range 1 (0-5.8)	Ref	Ref	Ref	Ref	Ref	Ref
Range 2 (5.8-10.8)	1.28 (0.85, 1.94)	1.09 (0.70, 1.69)	1.16 (0.74, 1.81)	0.95 (0.59, 1.52)	1.13 (0.75, 1.70)	0.93 (0.60, 1.43)
Range 3(10.8-18.95)	1.03 (0.67, 1.59)	0.85 (0.54, 1.34)	1.19 (0.75, 1.90)	0.97 (0.60, 1.59)	1.08 (0.71, 1.66)	0.92 (0.58, 1.44)
Range 4(18.95-199)	0.73 (0.46, 1.15)	0.83 (0.53, 1.31)	0.66 (0.39, 1.10)	0.47 (0.47, 1.30)	0.83 (0.53, 1.29)	0.97 (0.62, 1.50)

[a] Age adjusted for insurance and distance; SES adjusted for age and race; Insurance adjusted for age, race, and SES; Distance adjusted for age, race, SES and insurance

Figures and Figure Legends

Figure 1. Directed Acyclic Graph Demonstrating the Effect of Race on Delay

Figure 2. Directed Acyclic Graph Demonstrating the Effect of Age on Delay

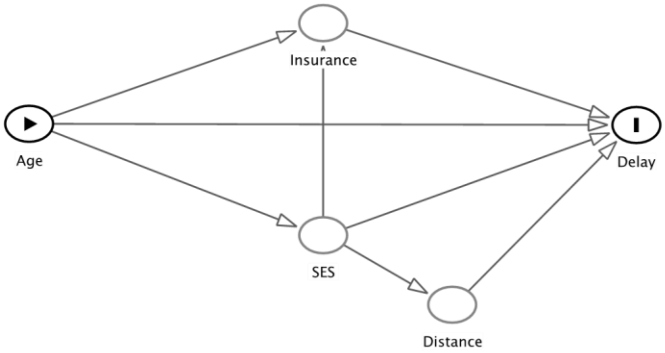


Figure 3. Directed Acyclic Graph Demonstrating the Effect of Insurance on Delay

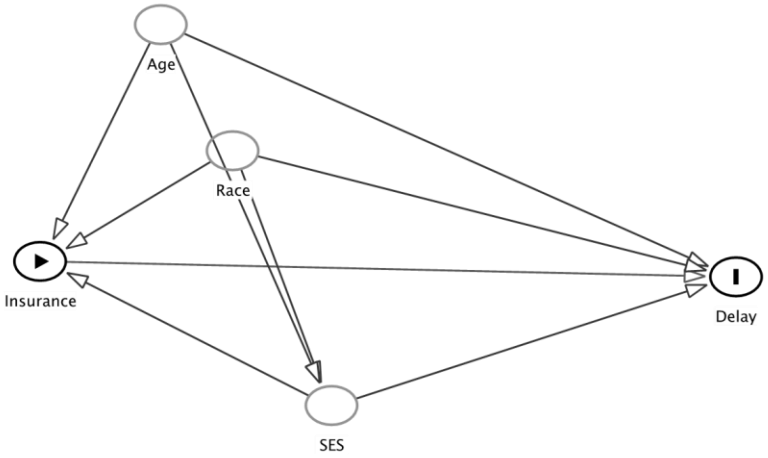


Figure 4. Directed Acyclic Graph Demonstrating the Effect of Distance on Delay

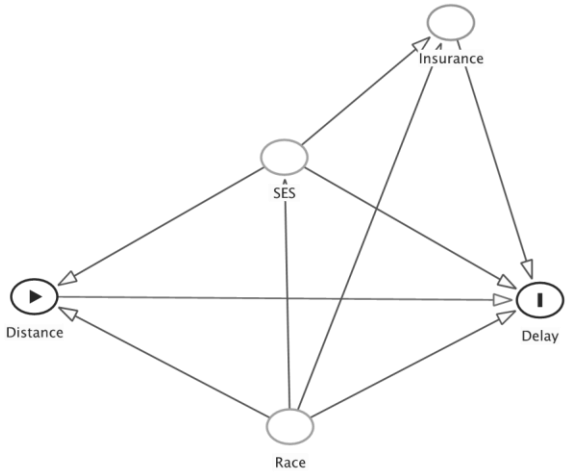
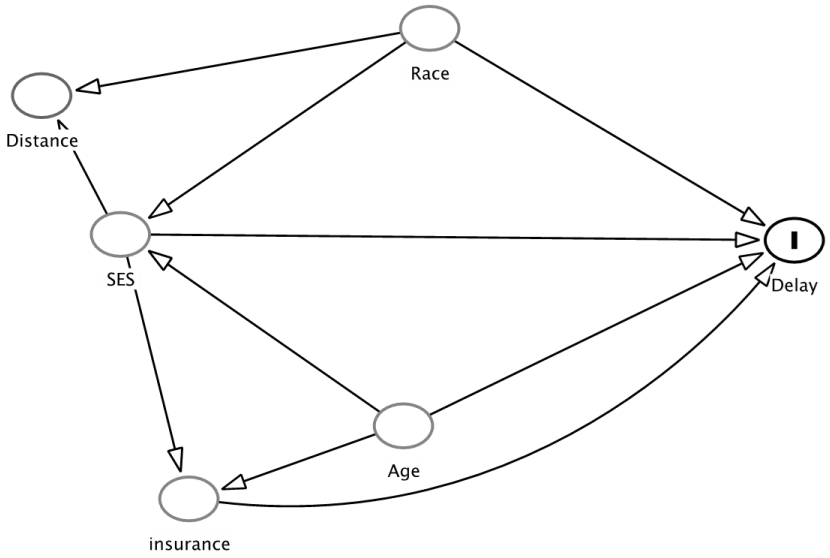


Figure 5. Directed Acyclic Graph Demonstrating the Effect of SES on Delay



Appendix

Supplemental Table 1: Demographic characteristics by screening delay characteristics (average BX Days, DX Days, and LOC Days) among 806 women who underwent breast cancer screening prior to a breast cancer diagnosis in the metropolitan Atlanta area (2010-2014).

		Diagnostic Mammography Delay		Biopsy Delay		Total delay	
Demographic Characteristics		<30 days	≥30 days	<15 days	≥15 days	<45 days	≥45 days
		n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Race/Ethnicity							
	White	294 (73.5)	106 (26.5)	333 (83.3)	67 (16.8)	292 (72.5)	111 (27.5)
	Black	242 (60.2)	160 (39.8)	269 (66.9)	133 (33.1)	225 (55.8)	178 (44.2)
Age Category							
	<55	47 (69.12)	21 (30.88)	53 (77.94)	15 (22.06)	46 (67.65)	22 (32.35)
	55-65	139 (66.83)	69 (33.17)	155 (74.52)	153 (25.48)	132 (63.46)	76 (36.34)
	66-75	146 (63.76)	83 (36.24)	176 (76.86)	53 (23.14)	145 (62.77)	86 (37.23)
	>75	588 (75.48)	191 (24.52)	204 (74.45)	70 (25.55)	180 (65.45)	95 (34.55)
Socioeconomic Status							
	Quartile 1($13,000-$37,000)	112 (60.22)	74 (39.78)	129 (69.35)	57 (30.65)	108 (57.75)	79 (42.25)
	Quartile 2 ($37,000-$50,000)	124 (63.59)	71 (36.41)	137 (70.26)	58 (29.74)	120 (61.54)	75 (38.46)

Quartile 3 ($50,000-$67,000)	129 (68.25)	60 (31.75)	145 (76.72)	44 (23.28)	125 (65.79)	65 (34.21)
Quartile 4 ($67,000-$150.000)	162 (74.31)	56 (25.69)	178 (81.65)	40 (18.35)	154 (70)	66 (30)
Insurance Status						
Private (BLUE CROSS, HMO PPO)	277 (66.11)	142 (33.89)	321 (76.61)	98 (23.39)	269 (63.74)	153 (36.26)
Medicare	219 (67.38)	106 (32.62)	241 (74.15)	84 (25.85)	212 (65.03)	114 (34.97)
Medicaid	9 (64.21)	5 (37.51)	8 (57.14)	6 (42.86)	7 (50)	7 (50)
Self-Pay	17 (73.91)	6 (26.09)	14 (60.87)	9 (39.13)	13 (56.52)	10 (43.48)
Geographical Distance to Screening Facilities (Miles)						
Range 1 (0-5.8)	135 (66.83)	67 (33.17)	151 (74.75)	51 (25.25)	130 (64.36)	72 (36.54)
Range 2 (5.8-10.8)	120 (61.54)	75 (38.46)	139 (71.28)	56 (28.72)	121 (61.42)	76 (38.58)
Range 3(10.8-18.95)	123 (67.58)	59 (32.42)	130 (71.43)	52 (28.57)	115 (63.19)	67 (36.81)
Range 4(18.95-199)	137 (71.73)	54 (28.27)	153 (80.10)	38 (19.90)	130 (67.36)	63 (32.64)

[a] Age adjusted for insurance and distance; SES adjusted for age and race; Insurance adjusted for age, race, and SES; Distance adjusted for age, race, SES and insurance

Supplemental Table 2: Association between patient demographic characteristics and average screening delay among 806 white and black women diagnosed with breast cancer in Atlanta (2010-2014) multi-variable and age adjusted.

Demographic Characteristics	Average DX Days		Average BX Days		Total Delay Days	
	Age-adjusted β (95%CI)	*Adj[a] β (95%CI)	Age-adjusted β (95%CI)	*Adj[a] β (95%CI)	Age-adjusted β (95%CI)	*Adj[a] β (95%CI)
Race/Ethnicity						
White	Ref	Ref	Ref	Ref	Ref	Ref
Black	-0.35 (8.87, 8.17)	1.10 (-7.05, 9.24)	5.44 (0.09, 10.80)	5.52 (0.47, 10.58)	4.96 (5.04, 14.96)	6.28 (-3.24, 15.8)
Age Category						
<55	Ref	Ref	Ref	Ref	Ref	Ref
55-65	-4.90 (-21.48, 11.69)	-6.93 (-24.74, 10.88)	6.45 (-4.00, 16.90)	6.56 (-4.77, 17.88)	1.55 (-17.96, 21.07)	-0.37 (-21.37, 20.63)
66-75	1.93 (-14.52, 18.38)	-1.13 (-18.90, 16.63)	6.01 (-5.28, 17.30)	6.80 (-3.57, 17.17)	8.68 (-10.66, 28.01)	4.67 (-16.25, 25.59)
>75	-5.37 (-21.47, 10.73)	-5.86 (-25.18, 13.47)	2.25 (-10.04, 14.53)	5.57 (-3.57, 17.17)	-0.00 (-18.94, 18.93)	-4.42 (-27.15, 18.32)
Socioeconomic Status	Ref	Ref	Ref	Ref	Ref	Ref
Quartile 1($13,000-$37,000)	5.9 (-6.15, 17.95)	6.94 (-6.08, 19.96)	2.94 (-4.74, 10.62)	-0.01 (-8.28, 8.27)	8.57 (-5.61, 22.75)	6.71 (-8.63, 22.04)
Quartile 2 ($37,000-$50,000)	1 (-10.81, 12.08)	1.99 (-10.72, 14.70)	1.96 (-5.56, 9.49)	-0.85 (-8.89, 7.23)	3 (-10.91, 16.92)	1.23 (-13.75, 16.22)
Quartile 3 ($50,000-$67,000)	0.93 (-10.92, 12.79)	1.4 (-10.66, 13.45)	0.27 (-7.29, 7.82)	-1.05 (-8.72, 6.62)	1.22 (-12.76, 15.19)	0.39 (-13.83, 14.60)
Quartile 4 ($67,000-$150.000)	Ref	Ref	Ref	Ref	Ref	Ref

Insurance Status						
Private (BLUE CROSS, HMO PPO)	Ref	Ref	Ref	Ref	Ref	Ref
MEDICAID	22.77 (-9.38, 54.92)	25.3 (-8.05, 58.65)	3.91 (-17.35, 25.17)	3.91 (-17.35, 25.17)	29.34 (-10.04, 68.72)	29.34 (-10.04, 68.72)
MEDICARE	-4.7 (-16.80, 7.40)	-6.39 (-18.53, 5.74)	1.82 (-5.9, 9.56)	1.82 (-5.9, 9.56)	-3.53 (-17.78, 10.72)	-3.53 (-17.78, 10.72)
Self-Pay	-6.41 (-32.22, 19.41	-6.36 (-32.07, 19.34)	4.4 (-11.98, 20.79)	4.4 (-11.98, 20.79)	-1.72 (-32.06, 28.63)	-1.72 (-32.06, 28.63)
Geographical Distance to Screening Facilities (Miles)						
Range 1 (0-5.8)	Ref	Ref	Ref	Ref	Ref	Ref
Range 2 (5.8-10.8)	-3.16 (-15.07, 8.74)	-4.74 (-17.21, 7.72)	3.96 (-3.61, 11.52)	2.9 (-5.05, 10.86)	0.23 (-13.78, 14.24)	-2.42 (-17.10, 12.26)
Range 3(10.8-18.95)	-6.08 (-18.39, 6.23)	-7.91 (-20.79, 4.97)	-1.42 (-9.24, 6.40)	-2.77 (-10.99, 5.44)	-7.53 (-22.05, 6.99)	-10.65 (-25.85, 4.56)
Range 4(18.95-199)	-1.14 (-13.65, 11.37)	-1.67 (-14.56, 11.23)	-1.22 (-9.17, 6.72)	-0.47 (-8.70, 7.76)	-2.09 (-16.82, 12.65)	-1.81 (-17.01, 13.39)
*Adjusted						

[a] Age adjusted for insurance and distance; SES adjusted for age and race; Insurance adjusted for age, race, and SES; Distance adjusted for age, race, SES and insurance

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