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Exploring Breast Cancer Care Variation in CoC-Accredited Facilities

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EXPLORING BREAST CANCER CARE VARIATION IN COC-ACCREDITED FACILITIES

by

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ABSTRACT

INTRODUCTION: While improvements have been made in reducing breast cancer incidence and mortality over the past twenty years, disparities in breast cancer mortality remain. Understanding systematic differences in breast cancer treatment and quality of care remain at the epicenter of understanding breast cancer disparities. Needle biopsy is a less invasive and less expensive diagnostic test for breast cancer (as compared to excisional biopsy) and permits diagnosis while avoiding unnecessary surgery. This study was conducted to 1) examine how the National Quality Forum (NQF)-endorsed needle biopsy utilization measure varies geographically (i.e. state and region) and 2) determine the patient- and/or health system-level factors that predict guideline concordance among women with breast cancer who received treatment at Commission on Cancer-accredited facilities. **METHODS:** Patients who received a breast cancer diagnosis from January 1, 2004 to December 31, 2015 were selected from the National Cancer Database, which captures information from over 70% of newly diagnosed breast cancers in the United States. Patients whose breast cancer was diagnosed by needle biopsy were compared with patients who did not receive needle biopsy to diagnose their breast cancer by analyzing patient-, tumor-, and facility-level factors. Generalized linear mixed modeling was used to identify important predictors of needle biopsy receipt. **RESULTS:** Of 1,362,417 patients, 78.8% had received needle biopsy to diagnose their breast cancer. Patients were significantly more likely to undergo needle biopsy if they were nonwhite, had health

insurance coverage through Medicaid or were uninsured/unknown form of insurance, had a comorbidity index score of 0, and were diagnosed with T3 lesions. Facility-level predictors of needle biopsy receipt were being diagnosed at a facility in the New England census region and being diagnosed at a medium/high case volume facility. Patients who resided in metropolitan areas of 1 million people or more had increased odds of receiving a needle biopsy as compared to individuals from smaller urban and rural areas.

CONCLUSION: This study suggests the significant impact that individual- and facility-level predictors have in reducing health inequalities in breast cancer to support the optimization of facility access, thus reducing breast cancer treatment disparities across patient populations.

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LIST OF ABBREVIATIONS

ASCO ..... American Society of Clinical Oncology

AUC ..... Area Under the Curve

CI ..... Confidence Interval

COC ..... Commission on Cancer

CP3R ..... Cancer Program Practice Profile Reports

ESMO ..... European Society for Medical Oncology

FIPS ..... Federal Information Processing Standard

FNA ..... Fine Needle Aspiration

IOM ..... Institute of Medicine

NCDB ..... National Cancer Database

NCI ..... National Cancer Institute

NQF ..... National Quality Forum

OR ..... Odds Ratio

PUF ..... Participant Use File

ROC ..... Receiver Operating Characteristic

SEER ..... Surveillance, Epidemiology, and End Results

CHAPTER 1

INTRODUCTION

Breast Cancer Burden in the United States

Breast cancer affects approximately 237,000 women in the United States annually (1). Among women, breast cancer is the leading cause of cancer incidence and the second-leading cause of cancer deaths in the United States (2). Breast cancer is a disease in which abnormal cells in the breast divide uncontrollably. If left untreated, breast cancer can spread outside the breast through blood vessels and lymph vessels and metastasize to other parts of the body. Breast cancer incidence rates in the U.S. began decreasing in 2000 due to advancements in detection through screening leading to declining incidence and mortality (3–6).

Disparities in Breast Cancer Care

While there has been effort in improving breast cancer prevention and treatment, inconsistencies remain within breast cancer care. In 1999, an Institute of Medicine (IOM) report articulated that many patients were receiving suboptimal treatment for their cancer. For instance, the report identified the lack of adherence to standards for diagnosis, inadequate patient counseling regarding treatment options, and underuse of radiation therapy and adjuvant chemotherapy after surgery as the main quality issues in breast cancer care (7). The report defined quality cancer care as "providing patients with

appropriate services in a technically competent manner, with good communication, shared decision making, and cultural sensitivity (7).“ Upon publication of this report, a plethora of organizations, including the National Quality Forum (NQF), used the 1999 report to develop performance measures related to the diagnosis and treatment of various cancers, including breast cancer (8). In 1994, 56% of women aged 50 and older had received a mammogram to detect breast cancer within the past 2 years. However, due to the incorporation of quality standards as a result of the IOM report, the prevalence of mammography has increased to 67% for women aged 50 and older as of 2015.

Studies have shown that socioeconomic, racial, and geospatial disparities exist in breast cancer treatment (9–13). For example, a cross-sectional study reported that 34% of black women, and 23% of Hispanic women failed to receive appropriate adjuvant therapy as compared to 16% of white women (14). Similarly, in a population-based study conducted in Georgia, black women had significantly increased odds of late stage diagnosis (OR 2.08, $p = 0.0001$) and decreased odds of surgery (OR 0.50, $p = 0.0001$) (15). Breast cancer patients often undergo complicated individualized treatment regimens involving a multitude of providers and settings of care. Providers face an expanding evidence base for treatment and can be limited in their treatment options based on the capabilities of their facility or access to technologies. Intervening through the health care setting by which breast cancer treatment is received presents feasible opportunities to improve cancer treatment across the realm of breast cancer (16).

Previous studies have identified deficiencies in quality of care for breast cancer patients (17,18) but few studies have examined guideline concordance for breast cancer patients across large geographic areas and multiple institutions (18–21). Health systems

likely contribute to the persistent variation observed across geographic areas in quality of care received, and ultimately health disparities (22). Elucidating factors driving breast cancer treatment disparities across geographic regions and population subgroups may inform interventions targeting modifiable patient- and/or provider-level care characteristics.

Quality of Breast Cancer Care Measurement

The NQF was created in 1999 to safeguard and improve patient protections and healthcare quality through measurement and reporting. The federal government relies on the NQF for evidence-based approaches for integrating new health policies and practices as well as evaluating performance of healthcare facilities. The NQF currently endorses 10 breast cancer treatment quality measures across realms of breast cancer surgery, diagnosis, and screening.

The American Society of Clinical Oncology (ASCO) has developed evidence-based clinical guidelines to provide physicians with an appropriate method of treatment and care. Among these guidelines include those specifically designed for the standardization of breast cancer treatment. The American College of Surgeons' Commission on Cancer (CoC), a coalition dedicated to improving survival and quality of life for cancer patients through standard-setting and monitoring quality of care, developed a similar series of breast cancer treatment quality metrics and submitted these metrics to the National Quality Forum. The American Society of Clinical Oncology and the CoC provide physicians and researchers with breast cancer treatment metrics endorsed by the National Quality Forum.

The National Cancer Database (NCDB) sources hospital registry data from more than 1,500 CoC-accredited facilities in the U.S. These data, which represent 70% of newly diagnosed cancer cases in the U.S., serve as the basis for quality improvement and are used to analyze and monitor patients with malignant forms of cancer, their treatment and outcomes. The CoC and the NCDB developed the NCDB Quality Reporting Tools to provide CoC-accredited cancer programs with the mechanisms needed to evaluate the cancer care delivery to their patients. Among these NCDB Quality Reporting Tools include the Cancer Program Practice Profile Reports (C3PR). C3PR currently utilizes three types of measures in the evaluation of breast cancer treatment: i) accountability measures promote improvements in care delivery and demonstrate physician accountability and transparency in services provided; ii) quality improvement measures function to monitor the need of quality improvement within individual programs; iii) surveillance measures used to monitor patters and trends of care while generating information for decision making.

Objective and Research Questions

The overall objective of this research is to examine variation in breast cancer treatment quality among CoC-accredited facilities using needle biopsy as a quality indicator of guideline-concordant breast cancer treatment. The research questions are:

1. How does needle biopsy receipt vary geographically (e.g. region)?
2. What patient and/or health system factors predict guideline-concordant needle biopsy utilization among women with breast cancer receiving treatment at CoC-accredited facilities?

Significance

Despite advances in breast cancer survival, treatment disparities persist for many quality indicators including needle biopsy utilization, breast-conserving surgeries, and timely use of radiation therapy (23,24). Metrics such as the NQF and CP3R allow for hospital performance benchmarking and inform surveillance and quality improvement strategies (20). Favorable scores on these metrics are potentially related to favorable prognosis among breast cancer patients (25). Additionally, research suggests that care quality favorably impacts breast cancer survival (26). While previous studies document geographic variation in breast cancer treatment, there is a dearth of information on why breast cancer treatment variation exists, as predicted by patient- and health system-level factors (21). If we learn why there is geographic variation in breast cancer treatment, improvements can be made in resource allocation and health policy decision-making, which would lead to increased breast cancer treatment guideline concordance and, in turn, improved breast cancer treatment and survival outcomes.

CHAPTER 2

LITERATURE REVIEW

2.1 MEASURES OF BREAST CANCER TREATMENT QUALITY

2.1.1 National Quality Forum

The NQF currently has 6 CoC and American College of Surgeons-endorsed measures that assess breast cancer treatment in the existing literature (Table 2.1).

2.1.2 Annals of Oncology Clinical Practice Guidelines

The Annals of Oncology Clinical Practice Guidelines were developed in accordance with the European Society for Medical Oncology (ESMO) standard operating procedures to assess breast cancer treatment. Levels of evidence through studies and surveillance and grades of recommendation are incorporated into this set of guidelines (26).

2.2 SOCIODEMOGRAPHIC PREDICTORS OF BREAST CANCER TREATMENT QUALITY

2.2.1 Race

Race plays a vital role as a predisposing factor in the diagnosis and survival of breast cancer (21,26–33). While non-Hispanic white women are more likely to be diagnosed with breast cancer, non-Hispanic black women are more likely to die from breast cancer (28). Hispanic women experience lower incidence and mortality rates of

breast cancer than non-Hispanic white women and non-Hispanic black women (28). There are a number of different factors that contribute to racial disparities in breast cancer survival and treatment, including the underuse of mammography screening and organizational differences within health facilities (11, 29).

Timely initiation to treatment is associated with increased survival rates among women with breast cancer. In a population-based study examining race and treatment delay, it was found that African American women experienced greater delay in treatment than white women among those who are less than 50 years old (30). More specifically, African American women were found to have begun treatment, on average, 6 days later after diagnosis than white women (31). Among women who were treated for breast cancer with surgery, mean time to surgery was higher in black women (mean 47 days) than white women (mean 33 days), further providing evidence that prolonged delays to breast cancer surgery exist among minorities (32).

Studies mentioned in this literature review utilized the NCDB, but a large portion of the studies selected to be included in this review of the literature used data from the National Cancer Institute's (NCI) Surveillance, Epidemiology, and End Results (SEER) Program. In particular, a cross-sectional study conducted in Georgia using SEER data examined the outcomes of late stage breast cancer diagnosis by race. In this study, non-Hispanic black women had significantly increased odds of late stage diagnosis and unknown tumor stage, decreased odds of receiving radiation or surgery, and increased risk of death following breast cancer diagnosis (15). A similar study conducted using SEER-Medicare linked data found racial disparities between black and white women in

receiving adjuvant chemotherapy and radiotherapy following breast-conserving surgery. According to this cross sectional study, black women with node-positive and node negative tumors were less likely (25% and 17%, respectively) to receive chemotherapy than white women after adjusting for patient and tumor characteristics (33).

The use of adjuvant therapy in the treatment of breast cancer has been widely accepted across different diagnostic stages of breast cancer. However, adherence to adjuvant therapy plays a vital role in the success of the treatment received. A study, using SEER data from 2001 to 2007, examined adjuvant endocrine therapy with chemotherapy adherence (evaluated by race). Investigators found that black women had lower initiation of adjuvant endocrine therapy (34, 35). Additionally, a cross-sectional study examining racial disparities in the adherence of adjuvant treatments for early-stage breast cancer found that minority women (defined as non-Hispanic black women and Hispanic women) with early-stage breast cancer have nearly double the risk of white women for failing to receive necessary adjuvant treatments despite rates of oncologic consultation similar to those of white women (14).

Several women elect to receive more aggressive forms of breast cancer treatment to minimize their risk of developing breast cancer subsequently in the future. The use of contralateral prophylactic mastectomy is increasing among women, partially due to increased awareness of genetic risks of breast cancer and improved reconstructive techniques. In a clinically administered survey issued from 2007-2009, it was found that black women were less likely than white women to undergo contralateral prophylactic mastectomy after adjustment for clinical factors and family history of breast cancer

(36). The findings of this study may be indicative of racial disparities in the patient-provider continuum.

Geography/residential status may be an intrinsic quality of racial disparities existing in breast cancer treatment. In a study examining SEER-Medicare data among white, black, and Hispanic women aged 66 to 85, investigators found that individuals who lived in areas with greater black segregation and greater Hispanic segregation were less likely to receive adequate breast cancer care, further contributing to the notion that segregation may act as a mediator for the racial disparity in breast cancer treatment (37).

2.2.2 Age

Age is recognized as a risk factor for developing breast cancer. Incidence rates of invasive breast cancer incidence increase from ages 40 to 65, but the incidence of breast cancer remains steady from age 65 until age 80 when incidence begins to decrease (38). These trends in data are likely a result of health initiatives to increase screening awareness among women of ages 45 to 50 (39).

A study using Surveillance, Epidemiology, and End Results (SEER)-Medicare data examined guideline concordance among metastatic breast cancer patients receiving systemic therapy in an elderly population (mean age at diagnosis was 76.5 years) (40). It was found that the mean age of diagnosis was 78.0 for those untreated versus 76.0 for those treated (adjusted $OR_{\text{age continuous/year}}$ 1.07, 95% CI: 1.04, 1.11) (40). The findings of this particular study suggest that non-receipt of recommended initial systemic therapy is more common among older women (40). Physicians and health policy officials could use these data to optimize treatment quality breast cancer-directed care for older populations of women with metastatic breast cancer.

A prospective cohort study was conducted in 2015 examining guideline concordant breast cancer treatment and individual-level factors among women with incident breast cancer in southwest Georgia (41). The results of this study indicated that women aged 50-64 years (OR 0.29, 95% CI: 0.15, 0.58) and 65 years and older (OR 0.30, 95% CI: 0.13, 0.71) were less likely to be guideline-concordant for chemotherapy compared to those who are younger than 50 years (41). Additionally, women aged 65 years and older were less likely to be guideline-concordant for hormonal therapy compared to those who are younger than 50 years (OR 0.50, 95% CI: 0.28, 0.90) (41).

Early stage breast cancer is typically treated with postoperative radiotherapy. If receipt of treatment is guideline concordant, the risk for local recurrence is reduced and likelihood of survival is prolonged (41–43). In a population-based study investigating patient compliance with radiotherapy after breast-conserving surgery, investigators explored age as a predictor of guideline concordance (44). This study found that noncompliance was associated with patient age ($p < 0.0005$) (44). Additionally, investigators found that compliance with radiotherapy was statistically higher in patients who received adjuvant hormone therapy than in patients who did not receive hormone therapy ($p < 0.0005$) (44). Omission of radiotherapy after breast-conserving surgery in patients with early breast cancer may lead to failure to control local tumors, which could negatively affect the prognosis of breast cancer patients.

In a study examining breast cancer treatment guidelines from 1998 – 2011 among breast conserving surgery recipients, it was observed that chemotherapy guideline adherence dropped steadily by age (45); 88.5% of women had guideline concordant

therapy under the age of 40, 80% in women aged 40-49, 67.7% in women aged 50-69, and 28.5% in women who were 70 years or older (45).

2.2.3 Education/Income

Education and income are key components that comprise socioeconomic status. A plethora of lifestyle and behavioral factors associated with education level and income may influence breast cancer risk, including age at first birth, physical activity, and participation in screening programs. Furthermore, factors associated with education and income may influence breast cancer survival, including adherence to breast cancer treatment guidelines.

Current treatment guidelines recommend breast conserving therapy for early stage breast cancers. Breast conserving therapy consists of breast conserving surgery followed by whole breast radiation therapy, endocrine therapy for women with invasive, hormone receptor positive breast cancer, and chemotherapy for patients with axillary lymph node positive disease regardless of receptor status. In a study analyzing trends in guideline adherence according to socioeconomic status, investigators sought to identify areas of improvement in breast conserving therapy (45). Women who belonged in the lowest education and income levels (individuals who did not graduate high school; individuals earning < $38,000) experienced disparities in breast conserving surgery for the duration of the study (45). Among women in the lower education and income levels, endocrine therapy guideline adherence rates were 68.5% in 2004-2006, but increased slightly to 74.8% (45).

A similar study conducted in 2012 found that women who resided in high-poverty and low-education areas were more likely to not adhere to breast cancer treatment

guidelines for chemotherapy (OR 0.77, 95% CI: 0.50, 0.86) (46). In the same study, women who reside in low-income areas and received hormonal therapy were less likely to receive guideline concordant treatment (OR 0.78, 95% CI: 0.64, 0.96) (46). The findings of this study suggest that inequities in breast cancer treatment prevail for women of low socioeconomic status, but offer no recommendation for the elimination of such inequities.

2.3 ACCESS TO CARE-RELATED ISSUES

2.3.1 Insurance Status

Current evidence suggests that disparities in insurance coverage among women with breast cancer is a predictor of receiving appropriate treatment (47, 48). Economic barriers experienced by women with a breast cancer diagnosis may contribute to worse outcomes for treatment, prognosis, and mortality (49, 50). Public screening programs catered towards women lacking insurance or women relying on public insurance may eliminate the disparities experienced among women who lack private insurance or who are not eligible for Medicare.

A significant predictor of non-guideline concordant chemotherapy is being covered through Medicaid insurance (OR 0.66, 95% CI: 0.50, 0.86) (46). Additionally, lacking insurance was found to be a predictor of nonguideline regimens among chemotherapy recipient (OR 0.47, 95% CI: 0.25, 0.92)(46).

A study examining guidelines for breast cancer treatment was conducted in Oklahoma among women who received breast conserving surgery (51). Women with a primary payer of Medicare/Medicaid (OR 0.45; 95% CI: 0.34, 0.62), Medicare (OR 0.59, 95% CI: 0.45, 0.78), and those without insurance (OR 0.37, 95% CI: 0.21, 0.64) had

significantly lower odds than those without private insurance to have met guidelines for breast conserving surgery (51).

Patterns of postoperative radiation therapy use varied according to insurance in a study conducted using data from National Cancer Institute Surveillance, Epidemiology, and End Results (52). Radiation therapy after breast conserving surgery was more frequently omitted in women with Medicaid or uninsured status ($p < 0.0001$) (52). The odds of omitting radiation therapy following breast conserving surgery remained significantly associated with Medicaid (OR 1.14; 95% CI: 1.07, 1.21) and uninsured status (OR 1.29; 95% CI: 1.14, 1.47) in multivariable analysis (52).

2.3.2 Distance to Facility and Rurality

Cancer patients who travel long distances to reach oncology care providers are at high risk of going untreated or being undertreated (53)(54). The influence of travel burden on cancer patients has been well documented in previous studies to suggest it negatively influences stage at diagnosis, appropriate treatment, prognosis, and quality of life (55). Breast cancer patients often require weekly and monthly healthcare services in order to closely and correctly follow the treatment regimen prescribed to them. Adherence to treatment guidelines may prove itself to be a difficult requirement in appropriateness of treatment among those who experience more travel distance to their treatment facility.

A study conducted in a rural region of the United States found a significant association between distance to treatment facility and guideline adherence (41). Compared to those residing within 5 miles of their treatment center, individuals living 5 – 22 miles away (OR 0.47; 95% CI: 0.26, 0.83) and greater than 22 miles away (OR 0.45,

95% CI: 0.22, 0.92) were less likely to be guideline-concordant for adjuvant hormonal therapy (41).

Travel distance to treatment facilities may be significantly associated with completion of abnormal mammogram follow-up (11). In a study conducted among women in South Carolina, it was found that women who lived farther from their diagnosing mammography facility experienced a longer lapse of time taken to resolve their abnormal mammogram, irrespective of race (11). In the same study, women who lived the closest to their diagnosing mammography facility were more likely to have completed an abnormal mammogram follow-up (11).

In a study examining the receipt of radiotherapy as a metric to reflect quality of breast cancer care, it was found that increasing distance to the nearest radiotherapy provider was significantly associated with lower odds of receiving radiotherapy (OR 0.54, 95% CI: 0.30, 0.97) for those living at least 20 miles from the nearest provider compared with those living less than 10 miles from the nearest provider (56). These findings may be indicative of the opportunities for public transportation among urban areas as opposed to the lack thereof in rural areas (56). The results of this study suggest that breast cancer patients living in areas greater than 10 miles from radiotherapy treatment facilities may need to be targeted for intervention to ensure they receive guideline-concordant care (56).

2.3.3 Physician Availability

In a study combining SEER data and the Health Resources and Services Administration Area Resource File to examine physician density and choice of breast conserving surgery versus mastectomy, the odds of having BCS versus mastectomy were

directly associated with radiation oncologist density (multiplicative change in odds for a single unit increase in radiation oncologist density [(ROD 1.02, 95% CI: 1.01–1.03); $p < 0.001$], stating that the average odds of a patient having BCS instead of mastectomy increase by 2% for each increase in the number of radiation oncologists per 100,000 people (57). Additionally, the multiplicative increase in odds for BCS for a single unit increase in radiation oncologist density was 1.06 (95% CI: 1.05, 1.07; $p < 0.001$), stating that for every increase in the number of radiation oncologists per 100,000 people, the average odds of a patient having BCS instead of mastectomy increased by 6% (57).

A retrospective cohort study observed that women who lived a long distance from a radiation therapy center (greater than or equal to 50 miles) had extremely low rates of breast conserving surgery with radiation therapy (15.8%) (58). Woman of this ≥50-mile cohort were most likely to undergo mastectomy (71.1%) (58). Women who lived 30-49 miles from radiation therapy had the next lowest rate of breast conserving surgery with radiotherapy (32.4%) and had a considerably high rate of mastectomy (64.1%)(58). In a similar study, distance to the closest radiation therapy facility was negatively associated with breast conserving surgery with radiation (per 5-mile increase: 0.97 (95% CI: 0.95, 0.99); per 10-mile increase: (95% CI: 0.90, 0.98) per 15-mile increase 0.91 (95% CI: 0.86, 0.96) per 20-mile increase 0.88 (95% CI: 0.82, 0.95))(59); the odds ratio decreased 3% per 5-mile increase in distance.

Table 2.1 National Quality Forum (NQF) Treatment Quality Measures[1]	
Measure	*Measure Specifications*
Radiation Therapy	Radiation therapy is administered within 1 year (365 days) of diagnosis for women under age 70 receiving breast conserving surgery for breast cancer.
Combination Therapy	Combination chemotherapy is recommended or administered within 4 months (120 days) of diagnosis for women under 70 with AJCC T1cN0M0 or Stage IB - III hormone receptor negative breast cancer.
Adjuvant Hormonal Therapy	Tamoxifen or third generation aromatase inhibitor is recommended or administered within 1 year (365 days) of diagnosis for women with AJCC T1cN0M0 or Stage IB - III hormone receptor positive breast cancer.
Radiation Therapy Following a Mastectomy	Radiation therapy is recommended or administered following any mastectomy within 1 year (365 days) of diagnosis of breast cancer for women with ≥ 4 positive regional lymph nodes.
Needle Biopsy	Image or palpation-guided needle biopsy to the primary site is performed to establish diagnosis of breast cancer.
Breast Conservation Surgery	Breast conservation surgery rate for women with AJCC clinical stage 0, I, or II breast cancer.

[1] Adapted from Cancer Programs Practice Profile Reports (CP3R) Rapid Quality Reporting System (RQRS). Released March, 2015. Accessed August 29, 2017.

CHAPTER 3

METHODS

3.1 STUDY DESIGN AND DATA SOURCE

We utilized an observational study design of breast cancer diagnosis and treatment data from 2004 to 2015 to analyze the association between i) geographic variation of needle biopsy receipt, and ii) patient- and/or health system predictors of guideline-concordant needle biopsy receipt among women with breast cancer diagnosed at CoC-accredited facilities. The data were obtained through the 2015 Participant Use File (PUF), which is derived from the NCDB. The NCDB is a collaborative program of the American College of Surgeons Commission on Cancer (CoC) and the American Cancer Society. Data represent a nationwide, hospital-based sample representing 70 percent of incident U.S. breast cancer cases. The data contained in the PUF have been de-identified in compliance with the Health Insurance Portability and Accountability Act (HIPAA) regulations.

3.2 STUDY POPULATION

Patients who received a breast cancer diagnosis from January 1, 2004, to December 31, 2015, at a CoC-accredited facilities who were female, aged 40+ years at diagnosis, had non-Phyllodes tumors, had in situ and invasive tumors, were diagnosed at

a physician office or at the reporting facility and treated or made a decision not to treat at the reporting facility were identified and included in the cross-sectional analysis for both aims of the study (described in Table 3.1). Patients were excluded if the patient refused care and diagnosis, was medically unable to hold position for an image guided biopsy, required sub-areolar excision for nipple discharge, had a lesion that was too superficial, had breasts that were too small, had a lesion inaccessible by needle biopsy, if cancer was found in prophylactic mastectomy or through an elective procedure, had a benign high risk lesion that was diagnosed by needle biopsy which then required excisional biopsy, had discordant biopsy results compared to suspicious imaging, if the patient presented with co-morbid conditions that directly impacts delivery of the standard of care, and/or if they were diagnosed via cytology fine needle aspiration (FNA) only.

3.3 MEASURES

Outcome Variable

The outcome variable of interest was needle biopsy utilization, which is a NQF-endorsed quality metric for breast cancer treatment. Needle biopsy was defined as having a core needle, fine needle aspiration, or incisional biopsy of the primary site performed for diagnosis.

Covariates

The focus of Aim 1 was geographic variation in needle biopsy receipt, specifically distance to facility and urban/rural status. The independent variables of interest for Aim 2 included patient- and health system factors (see list of variables and definitions below).

I. Geographic Variation

Geographic variation in needle biopsy receipt was accessed by rurality, which was categorized into metropolitan, urban, and rural strata and sub-strata in the PUF (using the typography published by the USDA Economic Research Service) and great circle distance. Rurality was determined by matching the state and county Federal Information Processing Standard (FIPS) code of the patient recorded at the time of diagnosis against 2013 urban-rural continuum codes published by the United States Department of Agriculture Economic Research Service (60). The matched codes form a classification scheme that distinguishes metropolitan counties by the population size of their metropolitan area, and nonmetropolitan counties by the degree of urbanization and adjacency to a metropolitan area. Rurality was categorized into three levels based on population (Table 4.1): metropolitan (counties in metro areas of more than 250,000 people), urban (counties with an urban population of 2,500 – 20,000 people or counties with an urban population of greater than 20,000 people), and rural (counties with less than 2,500 people). These three levels were then each subsequently stratified into nine sub-strata based off adjacency to metropolitan area (defined in Table 4.1). Great circle distance, measured in miles, was the computed distance between the patient's residence and the hospital that reported the case. Residential locations are based on the patient's ZIP code centroid or on the city if the ZIP code was not available. Hospital locations were based on the street address for the facility. Great circle distance was treated as a continuous covariate in all analyses, but was further interpreted as a continuous variable with 10-mile increments.

II. *Patient Factors*

Age of the patient was reported at her last birthday before diagnosis. Age was categorized into five groups (40-49, 50-59 years, 60-69 years, 70-79 years, and 80 years or more). Race was divided into White, Black, Hispanic, and Asian/Pacific Islander/Other according to the race self-reported by the patient. Median household income for each patient's area of residence was pre-coded by the NCDB through matching the ZIP code of the patient recorded at the time of diagnosis against files derived from the 2012 American Community Survey. Household income was categorized into quartiles based on equally proportioned income ranges among all US zip codes (<$38,000; $38,000 - $47,999; $48,000 - $62,999; $63,000 or more). Educational attainment was also pre-coded by the NCDB through matching the ZIP code of the patient recorded at the time of diagnosis against files derived from the 2012 American Community Survey. Educational attainment was a measure of the number of adults in the patient's ZIP code who did not graduate high school, and is categorized into quartiles among all U.S. ZIP codes (21% or more, 13% - 20.9%, 7% - 12.9%, less than 7%). The patient's primary insurance carrier at the time of initial diagnosis was pre-coded by the NDCB as Not Insured/Unknown, Private Insurance/Managed Care, Medicaid, Medicare, or Other Government. Comorbid conditions, as described by Charlson/Deyo in 1992, were analyzed from as many as ten reported ICD-9 or ICD-10 secondary diagnosis codes (61). The Charlson/Deyo Score is a weighted value derived from the sum of the scores from a selection of comorbid conditions (61). Individual Charlson/Deyo scores were not provided in the PUF. Instead, the Charlson/Deyo Score is derived from the highest score

that is calculated from using ICD-9 codes or the ICD-10 codes (Total Charlson/Deyo Score of 0; Total Charlson/Deyo Score of 1; Total Charlson/Deyo Score of 2; Total Charlson/Deyo Score of 3 or more).

In addition to the patient's residence and demographics being included in this study, tumor characteristics were also examined as a predictor of receiving needle biopsy. We examined the i) clinically-determined size and/or extension of the primary tumor; ii) clinically determined absence or presence of regional lymph node metastasis and the extent to which the regional lymph node metastasis; iii) the applicable stage group based on the size/extension, regional lymph node metastasis, and absence or presence of distant metastasis; and iv) the behavior (in situ/invasive) of all cases. All of the tumor characteristics were clinically input by physicians into the NCDB and defined by the American Joint Committee on Cancer (AJCC) staging system.

III. *Facility-level Factors*

Case volume was determined by calculating a weighted average of the number of breast cancer patients treated at each reporting cancer program and dividing programs into quintiles based on these averages. We calculated the case volume by facility for each year, then we took the 20^{th}, 40^{th}, 60^{th}, and 80^{th} percentiles to form five groups: Low (<71), Low/Medium (71-112), Medium (113-161), Medium/High (162-240), and High (>240). Facility type refers to an assigned classification given by the CoC program. Each facility reporting cases to the NCDB characterized facility type as a Community Cancer Program, Comprehensive Community Cancer Program, Academic/Research Program, Integrated Network Cancer Program, or Other. VA/Department of Defense facilities were not included in the PUF files, and therefore were not identifiable as a type of cancer

program (Figure 3.1)(62). Facility location was described by the US Census Division of the reporting facility (i.e., New England, Middle Atlantic, South Atlantic, East North Central, South Central, West North Central, West South Central, Mountain, and Pacific).

Statistical Analysis

All analyses were performed using SAS version 9.4 (Cary, North Carolina, USA). Geographic variation in needle biopsy receipt was described through great circle distance, region, and rurality. Patient-level factors and their association with guideline concordant care was described through age, race, income, education, insurance, comorbidity index, year of diagnosis, cancer behavior, clinical stage group, tumor size, and regional lymph node metastasis. The demographic characteristics were generated and reported as percentages for categorical variables and means and standard errors for continuous variables.

Confounder selection began before the main analysis. A descriptive table was created using frequencies with a test of significance based on the Chi-Square test among categorical variables in relation to needle biopsy utilization. Tests of significance among continuous variables used the standard two-sample t-test. Bivariate analysis for needle biopsy utilization as the dependent variable and patient-/facility-level factors was initially performed. Any potential covariate with a p-value of <0.20 in a series of bivariate analyses were added to a full model. After the full model was produced, a backward confounder reduction process was conducted to remove covariates one at a time. If the beta coefficient was changed by 10% upon removing the coefficient, it was placed back into the model. Statistically significant covariates remained in the model.

The main analysis, which examined the utilization of needle biopsy (1 = needle biopsy was utilized to diagnose breast cancer patient, 0 = needle biopsy was not utilized to diagnose breast cancer patient) across patient- and facility-level variables, was conducted through multivariable logistic regression modeling. In total, we ran three models: The first model was a model containing no fixed effects but only a random effect for facility nested within geographic area through an intercept; the second model contained individual-level covariates as fixed effects and the random effect term for facility nested within geographic area through an intercept; the final model contained individual- and facility-level covariates in addition to the random effect term for facility nested within geographic area through an intercept. Statistical significance was set at $p \leq 0.05$. Because our research question seeks to explore patient- and facility-level variation, the third model would be the most appropriate model to use in answering our research questions. The final model was a mixed effects model, with a random intercept for each facility nested within the facility location and fixed effects coefficients for the individual- and facility-level covariates. To capture how effective model 3 is at analyzing needle biopsy receipt, we used the area under the curve (AUC) of a Receiver Operating Characteristics curve (ROC). The ROC is a probability curve while the AUC represents the extent to which the model is capable of distinguishing between outcomes; in this case, our binary outcome of needle biopsy receipt.

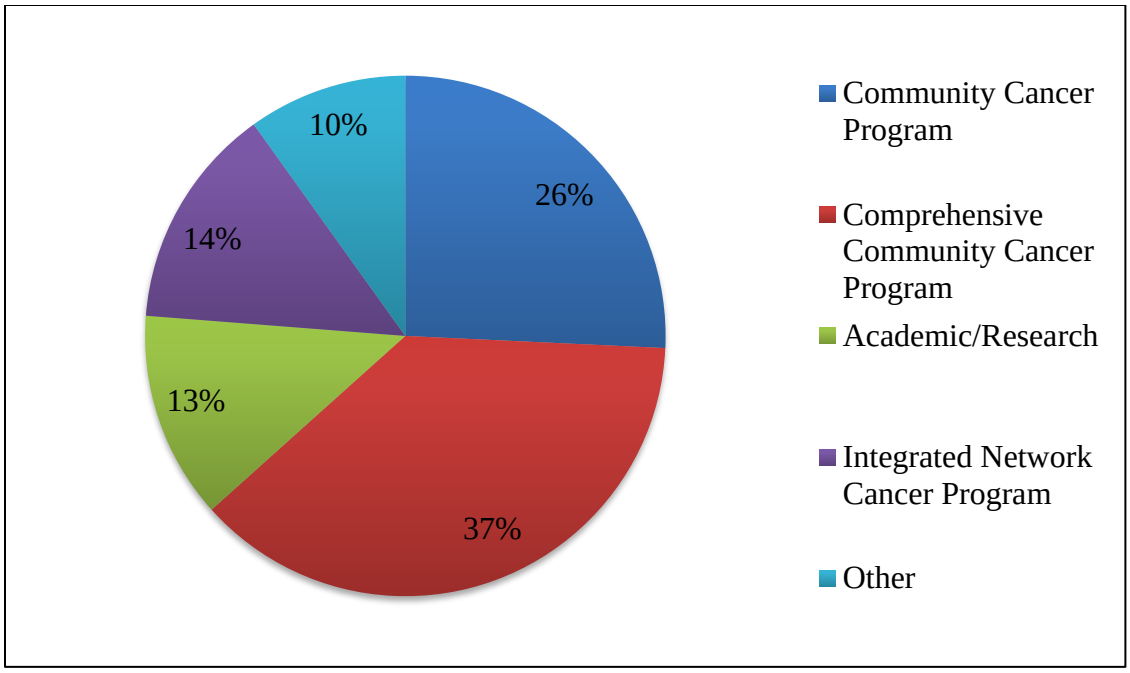

Figure 3.1 CoC-Accredited Facility Type

Table 3.1 Inclusion and Exclusion Criteria

Inclusion Criteria	**Exclusion Criteria**
40+ years Women Primary cancer site is breast Women with non-Phyllodes tumors Women with in situ and invasive tumors Women whose cases were diagnosed at staff physician office or at the reporting facility and treated or made decision not to treat at reporting facility Women who underwent biopsy (incisional, needle, aspiration) to primary site to establish diagnosis	Patient refusal Patient medically unable to hold position for image guided biopsy Patient requires sub-areolar excision for nipple discharge Lesion is too superficial Breast is too small Lesion inaccessible by needle biopsy Cancer found in prophylactic mastectomy or through elective procedure Benign high-risk lesions diagnosed by needle biopsy, requiring excisional biopsy Discordant biopsy results compared to suspicious imaging Patient presents with co-morbid conditions that directly impacts delivery to the standard of care Diagnosed by cytology fine needle aspiration only Women with metastatic disease

CHAPTER 4

EXPLORING GEOGRAPHIC VARIATION AND PREDICTORS OF NEEDLE BIOPSY UTILIZATION IN COC-ACCREDITED FACILITIES[1]

[1] S. Barron, J. Eberth, A. Zgodic S. Adams, J. Hussey, D. Blackhurst, M. Hudson. To be submitted to Journal of Oncology Practice.

ABSTRACT

INTRODUCTION: While improvements have been made in reducing breast cancer incidence and mortality over the past twenty years, disparities in breast cancer mortality remain. Understanding systematic differences in breast cancer treatment and quality of care remain at the epicenter of understanding breast cancer disparities. Needle biopsy is a less invasive and less expensive diagnostic test for breast cancer (as compared to excisional biopsy) and permits diagnosis while avoiding unnecessary surgery. This study was conducted to 1) examine how the National Quality Forum (NQF)-endorsed needle biopsy utilization measure varies geographically (i.e. state and region) and 2) determine the patient- and/or health system-level factors that predict guideline concordance among women with breast cancer who received treatment at Commission on Cancer-accredited facilities. **METHODS:** Patients who received a breast cancer diagnosis from January 1, 2004 to December 31, 2015 were selected from the National Cancer Database, which captures information from over 70% of breast cancers in the United States. Patients whose breast cancer was diagnosed by needle biopsy were compared with patients who did not receive needle biopsy to diagnose their breast cancer by analyzing patient-, tumor-, and facility-level factors. Generalized linear mixed modeling was used to identify important predictors of needle biopsy receipt. **RESULTS:** Of 1,362,417 patients, 78.8% had received needle biopsy to diagnose their breast cancer. Patients were significantly more likely to undergo needle biopsy if they were nonwhite, had health insurance coverage through Medicaid or were uninsured/unknown form of insurance, had a comorbidity index score of 0, and were diagnosed with T3 lesions. Facility-level predictors of needle biopsy receipt were being diagnosed at a facility in the New England

census region and being diagnosed at a medium/high case volume facility. Patients who resided in metropolitan areas of 1 million people or more had increased odds of receiving a needle biopsy as compared to individuals from smaller urban and rural areas.

CONCLUSION: This study suggests the significant impact that individual- and facility-level predictors have in reducing health inequalities in breast cancer to support the optimization of facility access, and, thus, reduce breast cancer treatment disparities across patient populations.

INTRODUCTION

In the United States, an estimated 268,600 new cases of invasive breast cancer are expected to be diagnosed among women in 2019 along with 62,930 cases of non-invasive breast cancer (63). Irrespective of race and ethnicity, breast cancer is the most common cancer and the second leading cause of cancer death among women in the United States (1). While social, medical, and technological improvements have been made in reducing breast cancer incidence and mortality, disparities in breast cancer treatment and quality of care remain at the epicenter of understanding breast cancer mortality and improving the quality of life among breast cancer patients and survivors.

To help improve breast cancer treatment quality and reduce breast cancer mortality, metrics such as the National Quality Forum (NQF) and Cancer Program Practice Profile Reports (CP3R), were created to benchmark performance, inform surveillance, and provide insight into quality improvement strategies. Past research has shown that care quality favorably impacts breast cancer survival (25). Additionally, recent literature suggests that geographic variation in breast cancer treatment exists, which may lead to disparities in the receipt of breast cancer treatment (19,20,34). If we learn why geographic variation exists in breast cancer treatment, improvements can be made in resource allocation and health policy implementation. More urban influence- and rurality- informed policies and resources would subsequently lead to improvements in the adherence to breast cancer treatment guidelines and, successively, improved breast cancer treatment and survival outcomes.

The NCDB sources hospital registry data from more than 1,500 CoC-accredited facilities. Because these data represent 70% of newly diagnosed cancer cases in the U.S.,

this sample of data is representative of the U.S. population that have obtained a cancer diagnosis (64). The CoC and NCDB developed the NCDB Quality Reporting Tools to evaluate the cancer care delivery among patients of CoC-accredited facilities. Treatment disparities are prevalent across several NCDB quality indicators, such as needle biopsy utilization (19,20,65). Needle biopsy proves itself to be a more suitable aspect of breast cancer diagnosis, care, and treatment because it is a less invasive form of breast cancer diagnosis (as compared to excisional biopsy), less costly, and permits diagnosis while avoiding unnecessary surgery.

A cross-sectional study of needle biopsy receipt in CoC-accredited facilities conducted between 2003 and 2008 provided justification for this study (20). Using the same data source as the present study, Williams et al. examined predictors of needle biopsy utilization while also exploring how needle biopsy utilization increased over time. While their study provided insight into the relationship between key patient and facility-level factors and needle biopsy utilization, an updated assessment is needed to determine whether uptake and geographic disparities in needle biopsy receipt have improved. This study was conducted to 1) examine how the NQF-endorsed needle biopsy utilization measure varies geographically (region) and 2) determine the patient- and/or health system-level factors that predict guideline concordance among women with breast cancer who received treatment at CoC-accredited facilities. This study hypothesized that needle biopsy utilization will be less likely among individuals who have a greater circle distance to facility, are rural, less educated, older, are ethnic/racial minorities, not privately insured, and have a lower median household incomes.

METHODS

Data

The data were obtained through the 2015 Participant Use File (PUF) derived from the NCDB. Patients who received a breast cancer diagnosis from January 1, 2004 to December 31, 2015 at CoC-accredited facilities were identified and included in the cross-sectional analysis for both aims of the study. In addition to being female, patients were also required to be an adult with an age of 40 years and above, have non-Phyllodes tumors, had in situ and invasive tumors, were diagnosed at a physician office or at the reporting facility and treated or made a decision not to treat at the reporting facility (Table 3.1).

Geographic Variation

Geographic variation was examined through i) urban-rural status, ii) great circle distance, and iii) facility location. Rurality was estimated in the PUF by matching the state and five-digit county Federal Information Processing Standard (FIPS) code of the patient recorded at the time of diagnosis against 2013 urban-rural continuum codes derived from the U.S. Department of Agriculture and Economic Research Service (57). The FIPS-matched codes form a classification scheme that distinguishes metropolitan counties by the population size of their metropolitan area, and nonmetropolitan counties by the degree of urbanization and adjacency to a metropolitan area. From this classification, areas are then subdivided into three metropolitan and six nonmetropolitan groupings, which are determined by population size of the county and adjacency to metropolitan areas. Great circle distance, measured in miles, is based on the distance between residential locations (using the patient's ZIP code centroid) and hospital

locations (using the street address of the facility). In this analysis, great circle distance was analyzed as a continuous variable, but was further interpreted as a continuous variable with 10-mile increments.

Patient Factors

Age of the patient is reported at her last birthday before diagnosis. Age was categorized into five groups: 40-49, 50-59, 60-69, 70-79, and 80+. Race was divided into White, Black, Hispanic, Asian/Pacific Islander and Other, according to the race self-reported by the patient. Median household income for each patient's area of residence was pre-coded by the NCDB through matching the ZIP code of the patient recorded at the time of diagnosis against files derived from the 2012 American Community Survey data. Household income was categorized into quartiles based on equally proportioned income ranges among all US ZIP codes (<$38,000; $38,000 - $47,999; $48,000 - $62,999; $63,000 or more). Educational attainment was pre-coded by the NCDB through matching the ZIP code of the patient recorded at the time of diagnosis against files derived from the 2012 American Community Survey data. Educational attainment is a measure of the number of adults in the patient's zip code who did not graduate high school, and was categorized into quartiles among all US ZIP codes (21% or more, 13% - 20.9%, 7% - 12.9%, Less Than 7%). Comorbid conditions, as described by Charlson/Deyo in 1992 were analyzed from as many as ten reported ICD-9 or ICD-10 secondary diagnosis codes (61). The Charlson/Deyo Score is a weighted value derived from the sum of the scores from a selection of comorbid conditions (61). Individual Charlson/Deyo scores are not provided in the PUF. Instead, the Charlson/Deyo Score was derived from the highest score that is calculated from using ICD-9 codes or the ICD-10 codes (Total

Charlson/Deyo Score of 0; Total Charlson/Deyo Score of 1; Total Charlson/Deyo Score of 2; Total Charlson/Deyo Score of 3 or more). The patient's primary insurance carrier at the time of initial diagnosis was examined as a system-level exposure. Insurance status was pre-coded by the NCDB as Not Insured, Private Insurance/Managed Care, Medicaid, Medicare, or Other Government.

In addition to the patient's residence and demographics being included in this study, tumor characteristics will also be examined by status of needle biopsy receipt and as a predictor of receiving needle biopsy. We examined the i) clinically-determined size and/or extension of the primary tumor; ii) clinically determined absence or presence of regional lymph node metastasis and the extent to which the regional lymph node metastasis; iii) the applicable stage group based on the size/extension, regional lymph node metastasis, and absence or presence of distant metastasis; and iii) the behavior (in situ/invasive) of all cases. All of the tumor characteristics were clinically input by physicians into the NCDB and defined by the American Joint Committee on Cancer (AJCC) staging system.

Facility-Level Factors

Case volume was determined by calculating a weighted average of the number of breast cancer patients treated at each reporting cancer program and dividing programs into quintiles based on these averages. We calculated the case volume by facility for each year, then we took the 20^{th}, 40^{th}, 60^{th}, and 80^{th} percentiles to form five groups: Low (<71), Low/Medium (71-112), Medium (113-161), Medium/High (162-240), and High (>240). Facility type refers to an assigned classification given by the CoC Accreditation Program. Each facility reporting cases to the NCDB characterized facility type as a

Community Cancer Program, Comprehensive Community Cancer Program, Academic/Research Program, Integrated Network Cancer Program, or Other. VA/Department of Defense facilities are not included in the PUF files, and therefore were not identifiable as a type of cancer program (Figure 3.1)(62). Facility location was derived from the U.S. Census Division of the reporting facility. All fifty states were categorized into 9 regions based on geographical location.

Data Analysis

All analyses were performed using SAS version 9.4 (Cary, North Carolina, USA). Geographic variation in needle biopsy receipt was described through great circle distance, region, and rurality. Patient-level factors and their association with guideline concordant care was described through age, race, income, education, insurance, comorbidity index, year of diagnosis, cancer behavior, clinical stage group, tumor size, and regional lymph node metastasis. The demographic characteristics were generated and reported as percentages for categorical variables and means and standard errors for continuous variables.

Confounder selection began before the main analysis. A descriptive table was created using frequencies with a test of significance based on the Chi-Square test among categorical variables in relation to needle biopsy utilization. Tests of significance among continuous variables used the standard two-sample t-test. Bivariate analysis for needle biopsy utilization as the dependent variable and patient-/facility-level factors was initially performed. Any potential covariate with a p-value of <0.20 in a series of bivariate analyses were added to a full model. After the full model was produced, a backward confounder reduction process was conducted to remove covariates one at a time. If the

beta coefficient was changed by 10% upon removing the coefficient, it was placed back into the model. Statistically significant covariates remained in the model.

The main analysis, which examined the utilization of needle biopsy (1 = needle biopsy was utilized to diagnose breast cancer patient, 0 = needle biopsy was not utilized to diagnose breast cancer patient) across patient- and facility-level variables, was conducted through multivariable logistic regression modeling. In total, we ran three models: The first model was a model containing no fixed effects but only a random effect for facility nested within geographic area through an intercept; the second model contained individual-level covariates as fixed effects and the random effect term for facility nested within geographic area through an intercept; the final model contained individual- and facility-level covariates in addition to the random effect term for facility nested within geographic area through an intercept. Statistical significance was set at $p \leq 0.05$. Because our research question seeks to explore patient- and facility-level variation, the third model would be the most appropriate model to use in answering our research questions. The final model was a mixed effects model, with a random intercept for each facility nested within the facility location and fixed effects coefficients for the individual- and facility-level covariates. To capture how effective model 3 is at analyzing needle biopsy receipt, we used the AUC of a ROC.

RESULTS

Demographics of Overall Study Population

After exclusion criteria were applied, the study population included 1,362,417 women for the years used in this analysis of NCDB data (2004-2015). Sample characteristics of the patients in this study are displayed in Table 4.1. The number of

patients per year ranged from a low of 99,057 in 2004 to a high of 125,442 in 2015 (Table 4.1). Most patients were white (80.2%), earned an income of $63,000+ per year (37.1%), and were insured with private insurance or had managed care (50.9%). Most patients presented with stage I disease (35.4%), were from the South Atlantic (21.9%) and were treated at comprehensive community cancer programs (50.4%). The mean travel distance for patients was 16.0 miles, with most patients residing in metropolitan counties comprised of populations ≥1,000,000 (54.1%).

Needle Biopsy vs. Other Biopsy

Needle biopsy was performed for diagnosis in 78.8% of women. All patient, facility, and tumor factors examined were significantly different ($p < 0.0001$) in their distribution when stratified and compared by needle biopsy receipt (Table 4.2). The percentage of women receiving needle biopsy increases with comorbidity index, facility case volume, and year of diagnosis. Conversely, the trend of women receiving other forms of biopsy for breast cancer diagnosis decreased across all years in the study period. Of the women who were diagnosed with in situ forms of breast cancer, 66% were diagnosed using needle biopsy compared to 34% who were not diagnosed with needle biopsy. 82.8% of women with invasive forms of breast cancer were diagnosed with needle biopsy, compared to 17.2% of women that were diagnosed with other forms of biopsy.

Predictors of Needle Biopsy, 2004 – 2015

Median income and educational attainment of the population were dropped from the analyses in Model 2 ($p = 0.3934$ and 0.7831, respectively) and Model 3 ($p = 0.3220$ and 0.7116, respectively) because these covariates were not significant. While Model 2

represents individual-level factors that predict needle biopsy receipt, Model 3 was chosen as the final model as it displays all of the covariates, at the individual and facility level, that predict needle biopsy receipt. The AUC ROC at 0.7838, which was deemed satisfactory moving forward with the analysis. Because model 3 answers our research questions around needle biopsy receipt in relation to individual- and facility-level predictors, the AUC ROC obtained demonstrates that model 3 is capable of distinguishing between our binary outcome. The results of the logistic regression models run are displayed in Table 4.3. Factors that predicted receipt of needle biopsy were assessed over the entire study period (2004 – 2015).

I. Geographic Variation in Needle Biopsy Receipt

Odds ratios (ORs) for each stratum of rurality were less than 1.0, with our comparison group (Metropolitan Areas of 1,000,000+ people) having the highest odds of receiving needle biopsy treatment. For example, the odds of needle biopsy receipt among metropolitan areas of 250,000-1 million were 0.956 (OR 0.956, 95% CI: 0.930, 0.983) times the odds of needle biopsy receipt for individuals who live in metropolitan areas of greater than 1 million people. Therefore, patients who live in metropolitan areas of 150,000-1 million people have odds of needle biopsy receipt 4.4% lower than patients who live in metropolitan areas of greater than 1 million people. This trend is seen for other strata of rurality as well. Patients who are from urban areas of more than 20,000 and adjacent and nonadjacent to metropolitan areas people were, respectively, 13.9% (OR 0.861, 95% CI: 0.831, 0.892) and 13.4% (OR 0.866, 95% CI: 0.814, 0.922) less likely to receive needle biopsy than patients who were form metropolitan areas of greater than 1 million people. Patients from smaller urban areas of 2,500-19,999 that were adjacent and

nonadjacent to metropolitan areas were, respectively, 10.1% (OR 0.899, 95% CI: 0.869, 0.929) and 12.5% (OR 0.875, 95% CI: 0.834, 0.918) less likely to receive needle biopsy as compared to patients who were from metropolitan areas of more than 1 million people. Patients who are from rural areas with less than 2,500 people and not adjacent to a metropolitan area are 10.9% less likely to receive needle biopsy as compared to patients that are from metropolitan areas of more than 1 million people (OR 0.891, 95% CI: 0.834, 0.952). Similarly, patients who are from rural areas with less than 2,500 people and are adjacent to a metropolitan area are 11.5% less likely to receive needle biopsy as compared to patients that are from metropolitan areas of more than 1 million people (OR 0.885, 95% CI: 0.832, 0.942). The odds ratio estimates for great circle distance was computed by comparing the average distance for patients who received needle biopsy against patients who did not receive needle biopsy. In this sample, great circle distance yielded odds ratio estimates that were significant, but weak in magnitude. For a 10-mile increase in great circle distance, the odds of needle biopsy receipt decrease by a factor of 0.0043 (OR: 0.99957, 95% CI: 0.99956, 0.99958) compared to patients who do not receive needle biopsy.

II. Individual-Level Factors Predicting Needle Biopsy Receipt

Patients aged 50-59 years had odds of receiving needle biopsy 11.5% greater than patients aged 40-49 years (OR: 1.115, 95% CI: 1.099, 1.130). Patients who were 60-69 years of age at the time of diagnosis had the highest odds of needle biopsy receipt (OR 1.200, 95% CI: 1.182, 1.219) while patients who were 80 years of age or older had the lowest odds of needle biopsy receipt (OR: 0.975, 95% CI: 0.955, 0.996). Race was associated with needle biopsy receipt, but all OR estimates were weak in magnitude and

close to the null value of 1.0. Patients who were on Medicaid at the time of breast cancer diagnosis were 1.056 times as likely to receive needle biopsy than patients who had private insurance/managed care (OR 1.056, 95% CI: 1.031, 1.081). Interestingly, patients who had Medicare at the time of breast cancer diagnosis were 0.979 times as likely to receive needle biopsy than patients who had private insurance/managed care (OR 0.979, 95% CI: 0.965, 0.993). Because most patients in these data do not experience comorbidity, all OR estimates were less than 1.0; patients with a comorbidity index of 1 were 8.5% less likely to receive needle biopsy compared to individuals with a comorbidity index of 0 (OR 0.915, 95% CI: 0.902, 0.927). Individuals with a comorbidity index of 3+ were 14.9% less likely to receive needle biopsy compared to individuals with a comorbidity index of 0 (OR 0.851, 95% CI: 0.802, 0.902). Compared with patients diagnosed in 2004, those diagnosed in 2015 were 4.626 times as likely to receive needle biopsy (OR: 4.626, 95% CI: 4.513, 4.743). This increasing trend in odds ratio is prevalent for all years examined in this model. The strongest association in tumor size/extension is seen for patients with T3 tumors. Patients with T3 tumors were 10.671 times as likely to receive needle biopsy as compared to patients with T0 tumors of the breast (OR 10.671, 95% CI: 9.947, 1.450). Patients who had clinically-determined presence of regional lymph node metastasis classified as “Unknown” by the AJCC were 1.642 times as likely to undergo needle biopsy as compared to patients who have no presence of regional lymph node metastasis (OR 1.642, 95% CI: 1.610, 1.675). Patients diagnosed with stage I breast cancer have odds of receiving needle biopsy 45.6% lower than patients diagnosed with stage 0 breast cancer (OR 0.544, 95% CI: 0.521, 0.567). Patients diagnosed with an unknown stage of breast cancer had odds of receiving needle biopsy 66.1% lower than

patients diagnosed with stage 0 breast cancer (OR 0.339, 95% CI: 0.328, 0.351). Patients diagnosed with invasive forms of breast cancer were more likely to obtain needle biopsy as compared to patients with in-situ forms of breast cancer (OR 3.110, 95% CI: 3.057, 3.163).

III. Facility-Level Factors Predicting Needle Biopsy Receipt

Facility type was not significant when included in the full model; however, because facility type explores breast cancer care variation through facility-level factors, it was left in the analysis. Patients who had their breast cancer diagnosed at high case-volume facilities were 1.506 times as likely to undergo needle biopsy than patients who were diagnosed at low case-volume facilities (OR 1.506, 95% CI: 1.446, 1.568). Therefore, patients diagnosed at high case-volume facilities have odds of receiving needle biopsy 50.6% greater than patients diagnosed at low case-volume facilities. Patients who had their breast cancer diagnosed at medium/high case-volume facilities had the highest odds of receiving needle biopsy; patients diagnosed at medium/high case volume facilities have odds of receiving needle biopsy 53.8% greater than patients diagnosed at low case-volume facilities (OR 1.538, 95% CI: 1.489, 1.589). Patients who were diagnosed in the New England census region had a higher likelihood of having needle biopsy as compared to those diagnosed in other census regions. Patients who were diagnosed in the Middle Atlantic census region had odds of undergoing needle biopsy 32.2% lower than patients diagnosed in the New England census region (OR 0.678, 95% CI: 0.548, 0.840). Similarly, patients who were diagnosed in the East South Central census region had odds of receiving needle biopsy 7.4% lower than patients diagnosed in the New England census region (OR 0.926, 95% CI: 0.723, 1.186).

IV. Random Effect for Facility-Driven Variability in Needle Biopsy Receipt

In our analyses, for all three models, we used a random intercept for each facility nested within its geographic area. Therefore, each patient had an additional effect coming from the facility they are associated with when the models are conducted and analyzed. The variance and standard error of each of the random intercepts are reported in Table 4.4. In model 1, the model containing only the random effect of facility within region, the variance estimate is 0.6795 (95% CI: 0.628, 0.738). We conducted a Likelihood Ratio Test to examine whether the covariance estimate was different from 0. We obtained a p-value of <0.0001, indicating that there is significant variation between facilities when controlling for region and that this random intercept is needed in the model. Because the analysis in model 1 yielded a significant estimate, model 2 and model 3 were also conducted with the random effect estimate.

Model 2 displays the individual-level variables and the random effect, therefore we controlled for the variation that comes from the individual-level variables through fixed effects. After this individual-level variation is accounted for, the remaining variation is captured by the random effect, which was 0.7642 (95% CI: 0.706, 0.830). This significant estimate was higher than that of model 1, which was unexpected as the random effect estimate should have decreased because these individual-level covariates should have reduced the amount of free-floating variation in the data and, hence, should have captured more of the variation in needle biopsy receipt. More exploration as to why this result was obtained is needed.

Model 3 captures the individual-level variation with the facility-level covariates. The random effect estimate is 0.6785 (95% CI: 0.627, 0.736), therefore there is still

variation between facilities. However, although the random effect estimate decreased once facility-level variables were included in addition to individual-level variables, these covariates do not account for all of the possible variation between the facilities.

DISCUSSION

The present study demonstrated significant geographic, facility-level, and individual-level predictors of needle biopsy receipt. Needle biopsy use varied geographically, with patients from large metropolitan areas experiencing the highest odds of undergoing needle biopsy. Facility-level factors that were associated with needle biopsy receipt were hospital census region and facility case volume. Hospitals in the New England census region and high case-volume facilities were the strongest predictors of needle biopsy receipt at the facility-level. Individual-level factors that were associated with needle biopsy receipt were race, age, insurance status, and comorbidity index score. Tumor characteristics, such as tumor size/extension, lymph node metastasis, clinical stage group, and behavior, were also associated with needle biopsy receipt.

Individual-level factors in the present study most strongly associated with needle biopsy receipt were characteristics of the tumor, insurance status, and age, similar to Williams et al. (23). Our study also found that race yielded OR estimates that were attenuated towards the null value of 1.0. One possible interpretation of the associations that were considerably weak in magnitude is our lack of an interaction term in the regression analyses. Including an interaction term in our regression analyses would have allowed the relationship between needle biopsy receipt and an independent variable to differ across categorized levels of a second independent variable. Specifically, an

interaction term between comorbidity index and age would better explore a patient's risk and build a more accurate patient profile in predicting needle biopsy receipt.

The effect of socioeconomic status on quality of breast cancer care is explored throughout the scientific literature (40,41,44–47,49,50). In our analyses, area income and percentage of the population without a high school degree were not significant and were, thus, excluded from our study. Excluding these variables from our analysis put a greater emphasis on exploring individual-level predictors of needle biopsy receipt. Williams et al., however, found significant associations in income and percentage of population without a high school degree in their overall analysis, which they deemed were significant socioeconomic predictors of needle biopsy receipt (23). Once Williams et al. restricted the analysis to only the year 2008, however, the only sociodemographic predictors that were persistently associated with receipt of needle biopsy were race and percentage of population without a high school degree (23). This particular finding of Williams et al. and our study may be a result of i) a decrease in disparities over time among women diagnosed with breast cancer and/or ii) the increasing use of needle biopsy as compared to other forms of biopsy to diagnose breast cancer.

Facility case-volume is known to have an impact on breast cancer treatment quality (60). For example, Eberth et al. found that low case volume facilities were more likely to omit needle biopsy as compared to high case volume facilities (60). Our study added to this body of evidence by finding that patients who had received a breast cancer diagnosis at a high case volume facility were at increased odds of receiving needle biopsy. Furthermore, facility case volume was the strongest predictor of needle biopsy at the facility-level. Williams et al. suggest that facility case volume is more important than

facility type as a predictor for receiving needle biopsy (23). Our analysis confirmed this finding as well. Although facility type was insignificant in the regression analyses, it was left in the model to gain more insight into facility-level factors that predict needle biopsy receipt.

Tumor size/extension was the most significant individual-level predictor of needle biopsy receipt in our study. Individuals who had been diagnosed with T3 tumors had the highest odds of receiving needle biopsy as compared to the other sizes/extensions examined in this study. Williams et al. found that tumor stage was an important individual-level predictor. While tumor stage was a significant predictor of needle biopsy in our study, tumor size/extension had nearly 10-fold increases in odds as compared to tumor stage.

This study was limited through its use of pre-coded and pre-populated registry data obtained through the NCDB PUF. In particular, the coding for the diagnostic procedure does not distinguish core, FNA, and incisional biopsies. Incisional biopsy patients could not be reliably separated from the needle biopsy cohort. Therefore, the needle biopsy cohort includes this group of patients. Equivalently, we could not differentiate patients undergoing FNA from those that had core needle biopsy. This comparison would have added to the scientific body of literature by portraying a more in-depth view of needle biopsy methods and how they differ across patient populations. There are predictors of needle biopsy receipt that were not captured explicitly in our dataset, including the expertise of the physician and the specialty of the treating surgeon.

This present study demonstrates the individual- and facility-level predictors of needle biopsy while also exploring geographical variation in receipt of needle biopsy.

The large sample size of over a million patients from multiple institutions and facilities increases the robustness of the overall model and builds a theoretically sound framework into the patient profiles of individuals who receive needle biopsy as a diagnostic tool in their breast cancer. Our study also explores four different tumor characteristics and how they influence a patient's odds of needle biopsy receipt, which is an area of individual-level predictors that Williams et al. fail to examine.

In conclusion, we explored geographical variation in guideline concordant breast cancer care through rurality and urban influence as well as individual- and facility-level predictors of guideline concordant care in a nationally representative sample of over one million women. This study suggests the significant impact that individual- and facility-level predictors have in reducing health inequalities in breast cancer care to support the optimization of facility access, and, thus, reduce breast cancer treatment disparities across patient populations. Furthermore, this study adds to literature to build a more accurate and representative patient profile among individuals who receive breast cancer care that is in accordance to current practice guidelines. Having access to guideline-concordant breast cancer care is important in reducing the overall breast cancer burden. Breast cancer interventions should target low case-volume facilities in order to maximize the utilization of needle biopsy and, thus, conduct guideline concordant breast cancer care.

Table 4.1 Patient demographic and clinical characteristics of breast cancer patients from the NCDB, 2004 – 2015 (N = 1,362,417)

Characteristic	No. of Patients	%
Entire cohort	1,362,417	100%
Patient Factors		
Age, years		
40-49	234,282	17.2
50-59	346,569	25.4
60-69	365,267	26.8
70-79	265,452	19.5
80+	150,847	11.1
Race/Ethnicity		
White	1,092,506	80.2
Black	150,077	11.0
Hispanic	60,832	4.5
Asian/Pacific Islander	40,168	3.0
Other	18,834	1.4
Income		
<$38,000	202,206	14.9
$38,000-$47,999	285,980	21.0
$48,000-$62,999	367,413	27.0
$63,000+	505,378	37.1
Population Without HS Degree		
21%+	190,388	14.0
13%-20.9%	319,754	23.5
7% - 12.9%	457,657	33.6
<7%	393,710	28.9
Insurance Status		
Not Insured	25,324	1.9
Private Insurance/Managed Care	692,935	50.9
Medicaid	67,675	5.0
Medicare	546,812	40.1
Other Government	10,776	0.8
Insurance Status Unknown	19,195	1.4
Urban/Rural Residence		
Metro Counties:		
1 million+	400,115	55.3
250,000-1 million	161,948	22.4
<250,000	73,549	10.2
Urban Counties:		
20,000+, adjacent to metro area	27,713	3.8
20,000+, not adjacent to metro area	10,210	1.4

2,500-19,999, adjacent to metro area	28,231	3.9
2,500-19,999, not adjacent to metro area	11,807	1.6
Rural Counties:		
<2,500, adjacent to metro area	5,232	0.70
<2,500, not adjacent to metro area	4,690	0.70
Comorbidity Index		
0	1,134,788	83.3
1	184,056	13.5
2	34,218	2.5
3+	9,355	0.7
Year of Diagnosis		
2004	99,057	7.3
2005	100,751	7.4
2006	103,764	7.6
2007	107,824	7.9
2008	111,360	8.2
2009	116,166	8.5
2010	113,683	8.3
2011	117,332	8.6
2012	118,963	8.7
2013	122,890	9.0
2014	125,185	9.2
2015	125,442	9.2
Tumor Characteristics* **		
Tumor Size/Extension		
T0	7,918	0.6
Ti	271,339	19.9
T1	512,079	37.6
T2	197,561	14.5
T3	34,621	2.5
T4	24,270	1.8
Unknown	314,179	23.1
Lymph Node Metastasis		
N0	933,237	68.5
N1	14,956	1.1
N2	17,705	1.3
N3	8,133	0.6
Unknown	388,386	28.5
Clinical Stage Group		
0	265,768	19.5
I	482,004	35.4
II	227,886	16.7
III	57,846	4.2
Unknown	327,639	24.0
Behavior		

In situ	322,011	23.6
Invasive	1,040,406	76.4
	Mean	SD
Great Circle Distance, miles	16.0	64.8
Facility Factors		
Hospital Census Region		
New England	88,478	6.5
Middle Atlantic	211,484	15.5
South Atlantic	298,714	21.9
East North Central	264,852	19.4
East South Central	82,491	6.1
West North Central	107,171	7.9
West South Central	93,837	6.9
Mountain	84,299	4.0
Pacific	161,091	11.8
Facility Type		
Community Cancer Program	151,299	11.1
Comprehensive Community Cancer Program	686,815	50.4
Academic/Research Program	367,586	27.0
Integrated Network Cancer Program	156,717	11.5
Facility Volume		
Low (<71)	271,119	19.9
Low/Medium (71-112)	271,223	19.9
Medium (113-161)	272,413	20.0
Medium/High (162-240)	273,954	20.1
High (>240)	273,708	20.1

Comorbidity index is based on Charlson-Deyo score. Column percentages may not equal 100% due to rounding. **Abbreviations**: SE = Standard Error, HS = High School.

Table 4.2 Characteristics of breast cancer patients by needle biopsy receipt from the NCDB, 2004-2015 (N = 1,362,417)

Patient Factors	Needle Biopsy Receipt (n = 1,074,147) n	% [a, b]	No Needle Biopsy Receipt (n = 288,270) n	% [a, b]	P-value*
Age, years					<.0001
40-49	178,846	76.3	55,436	23.7	
50-59	272,565	78.6	74,004	21.4	
60-69	294,476	80.6	70,791	19.4	
70-79	211,624	80.0	53,828	20.0	
80+	116,636	77.3	34,211	22.7	
Race/Ethnicity					<.0001
White	859,901	78.7	232,605	21.3	
Black	118,700	79.1	31,377	20.9	
Hispanic	48,862	80.3	11,970	19.7	
Asian/Pacific Islander	32,102	79.9	8,066	20.1	
Other	14,582	77.4	4,252	22.6	
Income					<.0001
<$38,000	158,526	78.4	43,680	21.6	
$38,000-$47,999	226,363	79.2	59,617	20.8	
$48,000-$62,999	291,685	79.4	75,728	20.6	
$63,000+	396,481	78.5	108,897	21.5	
Population Without HS Degree					<.0001
21%+	150,133	78.9	40,255	21.1	
13% - 20.9%	250,974	78.5	68,780	21.5	
7% - 12.9%	360,682	78.8	96,975	21.2	
<7%	311,680	79.2	82,030	20.8	
Insurance Status					<.0001
Not Insured	20,515	81.0	4,809	19.0	
Private Insurance/Managed Care	542,068	78.2	150,867	21.8	
Medicaid	55,131	81.8	12,244	18.2	
Medicare	433,195	79.2	113,617	20.8	
Other Government	8,670	80.5	2,106	19.5	
Insurance Status Unknown	14,568	75.9	4,627	24.1	
Urban/Rural Residence					<.0001
Metro Counties:					
1 million+	345,508	86.4	54,607	13.6	
250,000-1 million	140,689	86.9	21,259	13.1	
< 250,000	64,426	87.6	9,123	12.4	
Urban Counties:					
20,000+, adjacent to metro area	23,867	86.1	3,846	13.9	
20,000+, not adjacent to metro area	8,849	86.7	1,361	13.3	

2,500-19,999, adjacent to metro area	24,602	87.1	3,629	12.9	
2,500-19,999, not adjacent to metro area	10,171	86.1	1,636	13.9	
Rural Counties:					
<2,500, adjacent to metro area	4,528	86.5	704	13.5	
<2,500, not adjacent to metro area	4,092	87.2	598	12.8	
Comorbidity Index**					<.0001
0	893,005	78.7	241,783	21.3	
1	146,105	79.4	37,951	20.6	
2	27,397	80.1	6,821	19.9	
3+	7,640	81.7	1,715	18.3	
Year of Diagnosis					<.0001
2004	61,381	62.0	37,676	38.0	
2005	65,875	65.4	34,876	34.6	
2006	70,789	68.2	32,975	31.8	
2007	76,311	70.8	31,513	29.2	
2008	82,191	73.8	29,169	26.2	
2009	90,868	78.2	25,298	21.8	
2010	93,448	82.2	20,235	17.8	
2011	100,083	85.3	17,249	14.7	
2012	103,445	87.0	15,518	13.0	
2013	107,752	87.7	15,138	12.3	
2014	110,915	88.6	14,270	11.4	
2015	111,089	88.6	14,353	11.4	
Tumor Characteristics***					
Tumor Size/Extension					<.0001
T0	3,129	39.5	4,789	60.5	
Ti	198,750	73.2	72,589	26.8	
T1	440,828	86.1	71,251	13.9	
T2	174,440	88.3	23,121	11.7	
T3	31,102	89.8	3,519	10.2	
T4	21,258	86.0	3,462	14.0	
Unknown	204,640	65.1	109,539	34.9	
Lymph Node Metastasis					<.0001
N0	759,044	81.3	174,193	18.7	
N1	10,846	72.5	4,110	27.5	
N2	15,042	85.0	2,663	15.0	
N3	6,959	85.6	1,174	14.4	
Unknown	282,256	72.7	106,130	27.3	
Clinical Stage Group					<.0001
0	193,757	72.9	72,011	27.1	
I	414,639	86.0	67,365	14.0	
II	200,595	88.0	27,291	12.0	
III	50,442	87.2	7,404	12.8	
Unknown	213,894	65.3	113,745	34.7	

Behavior					<.0001
In situ	212,579	66.0	109,432	34.0	
Invasive	861,568	82.8	178,838	17.2	
Great Circle Distance	Mean	SE	Mean	SE	<.0001[†]
Miles	15.6	0.06	17.0	0.14	
	Needle Biopsy Receipt (n = 1074147)		**No Needle Biopsy Receipt** (n = 288270)		
Facility Factors	n	%	n	%	P-value
Hospital Census Region					<.0001
New England	69,128	78.1	19,350	21.9	
Middle Atlantic	155,173	73.4	56,311	26.6	
South Atlantic	235,420	78.8	63,294	21.2	
East North Central	212,504	80.2	52,348	19.8	
East South Central	65,473	79.4	17,018	20.6	
West North Central	86,170	80.4	21,001	19.6	
West South Central	73,527	78.4	20,310	21.6	
Mountain	43,581	80.3	10,718	19.7	
Pacific	133,171	82.7	27,920	17.3	
Facility Type					<.0001
Community Cancer Program	112,520	74.4	38,779	25.6	
Comprehensive Community Cancer Program	544,256	79.2	142,559	20.8	
Academic/Research Program	290,117	78.9	77,469	21.1	
Integrated Network Cancer Program	127,254	81.2	29,463	18.8	
Facility Volume					<.0001
Low (<71)	198,466	73.2	72,653	26.8	
Low/Medium (71-112)	211,027	77.8	60,196	22.2	
Medium (113-161)	217,306	79.8	55,107	20.2	
Medium/High (162-240)	222,690	81.3	51,264	18.7	
High (>240)	224,658	82.1	49,050	17.9	

[a] Percentages are based on row percentages. [b] Row percentages may not equal 100% due to rounding. * Chi-square test is used to test for statistical significance at the $p \leq 0.05$ level. ** Comorbidity index is based on Charlson-Deyo score. Column percentages may not equal 100% due to rounding. *** Tumor characteristics are based on the ASCO. [†]The p-value for great circle distance is derived from a t-test. **Abbreviations**: SE = Standard Error, HS = High School.

Table 4.3 Individual- and facility-level factors predicting the odds of needle biopsy in 2004 – 2015

	Model 1	Model 2	Model 3[a,b]
Age			
40-49	Ref	Ref	Ref
50-59		**1.114 (1.099, 1.130)**	**1.115 (1.099, 1.130)**
60-69		**1.201 (1.182, 1.219)**	**1.200 (1.182, 1.219)**
70-79		**1.195 (1.172, 1.217)**	**1.194 (1.172, 1.217)**
80+		**0.975 (0.955, 0.996)**	**0.975 (0.955, 0.996)**
Race/Ethnicity			
White	Ref	Ref	Ref
Black		**1.033 (1.016, 1.050)**	**1.035 (1.018, 1.052)**
Hispanic		**1.047 (1.021, 1.074)**	**1.047 (1.021, 1.074)**
Other		**1.033 (1.008, 1.058)**	**1.033 (1.008, 1.058)**
Insurance Status			
Private Insurance/Managed Care	Ref	Ref	Ref
Not Insured/Insurance Status Unknown		**1.039 (1.010, 1.069)**	**1.040 (1.010, 1.070)**
Medicaid		**1.052 (1.028, 1.077)**	**1.056 (1.031, 1.081)**
Medicare		**0.977 (0.964, 0.991)**	**0.979 (0.965, 0.993)**

Other Government		1.026 (0.973, 1.083)	1.027 (0.973, 1.084)
Urban/Rural Residence			
1 million+	Ref	Ref	Ref
250,000-1 million		**0.956** **(0.930, 0.983)**	**0.956** **(0.930, 0.983)**
<250,000		**0.893** **(0.865, 0.922)**	**0.894** **(0.866, 0.923)**
20,000+, adjacent to metro area		**0.858** **(0.828 0.889)**	**0.861** **(0.831, 0.892)**
20,000+, not adjacent to metro area		**0.860** **(0.809, 0.905)**	**0.866** **(0.814, 0.922)**
2,500-19,999, adjacent to metro area		**0.897** **(0.868, 0.928)**	**0.899** **(0.869, 0.929)**
2,500-19,999, not adjacent to metro area		**0.872** **(0.831, 0.915)**	**0.875** **(0.834, 0.918)**
<2,500, adjacent to metro area		**0.882** **(0.830, 0.939)**	**0.885** **(0.832, 0.942)**
<2,500, not adjacent to metro area		**0.886** **(0.829, 0.946)**	**0.891** **(0.834, 0.952)**
Comorbidity Index			
0	Ref	Ref	Ref
1		**0.914** **(0.902, 0.927)**	**0.915** **(0.902, 0.927)**
2		**0.890** **(0.863, 0.917)**	**0.890** **(0.864, 0.918)**
3+		**0.852** **(0.803, 0.903)**	**0.851** **(0.802, 0.902)**

Year of Diagnosis			
2004	Ref	Ref	Ref
2005		**1.178 (1.154, 1.201)**	**1.177 (1.154, 1.201)**
2006		**1.383 (1.356, 1.411)**	**1.381 (1.353, 1.408)**
2007		**1.553 (1.522, 1.585)**	**1.547 (1.516, 1.578)**
2008		**1.624 (1.591, 1.658)**	**1.616 (1.583, 1.650)**
2009		**2.070 (2.026, 2.115)**	**2.045 (2.002, 2.090)**
2010		**2.662 (2.602, 2.723)**	**2.638 (2.579, 2.669)**
2011		**3.437 (3.537, 3.518)**	**3.387 (3.308, 3.468)**
2012		**4.025 (3.929, 4.123)**	**3.965 (3.870, 4.061)**
2013		**4.321 (4.217, 4.427)**	**4.261 (4.159, 4.366)**
2014		**4.837 (4.719, 4.958)**	**4.735 (4.619, 4.854)**
2015		**4.737 (4.622, 4.856)**	**4.626 (4.513, 4.743)**
Tumor Size/Extension			
T0	Ref	Ref	Ref
Ti		**4.416 (4.183, 4.661)**	**4.443 (4.209, 4.691)**
T1		**6.756 (6.378, 7.157)**	**6.813 (6.431, 7.217)**

T2		**9.288 (8.744, 9.866)**	**9.374 (8.824, 9.957)**
T3		**10.572 (9.856, 11.341)**	**10.671 (9.947, 11.450)**
T4		**8.132 (7.522, 8.792)**	**8.244 (7.625, 8.913)**
Unknown		**4.280 (4.057, 4.515)**	**4.325 (4.100, 4.563)**
Lymph Node Metastasis			
N0	Ref	Ref	Ref
N1		**1.382 (1.343, 1.422)**	**1.384 (1.345, 1.424)**
N2		**1.126 (1.060, 1.197)**	**1.128 (1.061, 1.199)**
N3		1.063 (0.983, 1.151)	1.064 (0.984, 1.152)
Unknown		**1.640 (1.611, 1.677)**	**1.642 (1.610, 1.675)**
Clinical Stage Group			
0	Ref	Ref	Ref
I		**0.545 (0.522, 0.568)**	**0.544 (0.521, 0.567)**
II		**0.480 (0.458, 0.503)**	**0.479 (0.457, 0.502)**
III		**0.468 (0.437, 0.501)**	**0.467 (0.437, 0.499)**
Unknown		**0.340 (0.329, 0.351)**	**0.339 (0.328, 0.351)**
Behavior			
In situ	Ref	Ref	Ref

Invasive		**3.109 (3.057, 3.162)**	**3.110 (3.057, 3.163)**
Great Circle Distance			
		0.999580 (0.999513, 0.999650)	**0.999570 (0.999563, 0.999576)**
Hospital Census Region			
New England	Ref	Ref	Ref
Middle Atlantic			**0.678 (0.548, 0.840)**
South Atlantic			0.884 (0.723, 1.081)
East North Central			1.016 (0.831, 1.242)
East South Central			**0.926 (0.723, 1.186)**
West North Central			1.114 (0.877, 1.414)
West South Central			0.865 (0.685, 1.091)
Mountain			1.022 (0.776, 1.346)
Pacific			1.176 (0.946, 1.462)
Facility Type			
Academic/Research Program	Ref	Ref	Ref
Community Cancer Program			0.913 (0.794, 1.051)
Comprehensive Community Cancer Program			1.014 (0.890, 1.154)

Integrated Network Cancer Program			1.041 (0.876, 1.235)
Facility Volume			
Low	Ref	Ref	Ref
Low/Medium			**1.281 (1.253, 1.309)**
Medium			**1.440 (1.401, 1.479)**
Medium/High			**1.538 (1.489, 1.589)**
High			**1.506 (1.446, 1.568)**

[a]Only variables significant on multivariable analysis are shown. [b]ROC AUC = 0.7838.

Table 4.4 Random effects covariance estimates from the NCDB, 2004 – 2015

	Model 1	**Model 2**	**Model 3**
Random Effect Type	Intercept	Intercept	Intercept
Covariance Estimate	0.6795	0.7642	0.6785
Standard Error	0.02783	0.03130	0.02777
95% Confidence Interval	(0.628, 0.738)	(0.706, 0.830)	(0.627, 0.736)
Statistical Test	Chi-square test of covariance Parameter = 0	Chi-square test of covariance Parameter = 0	Chi-square test of covariance Parameter = 0
Test Statistic	107043	109219	96249
Degrees of Freedom	1	1	1
P-Value	<.0001	<.0001	<.0001
AUC	-	-	0.7838

CHAPTER 5
CONCLUSION

Summary of Results

In summary, patients who had an increased likelihood of receiving guideline-concordant care were Hispanic, 60-69 years of age, had a comorbidity index score of 0, and had health insurance coverage through Medicaid. Patients who lived in metropolitan areas of 1 million people or more were more likely to receive guideline concordant breast cancer care through needle biopsy as compared with patients from urban and rural areas. Additionally, patients who received a diagnosis at a facility in New England were more likely to receive guideline-concordant care as compared to the 8 other U.S. census regions examined in this study. Patients who were diagnosed at high case volume facilities were more likely to receive guideline concordant treatment as compared to patients who were diagnosed at low case volume facilities.

Significance of Findings

The results from this study support findings from previous research on needle biopsy utilization from nationally-sourced datasets (23,60). Compared to the Williams et al. study, which was published in 2011 using data obtained from the NCDB PUF, our study has more pertinent data that builds a more accurate representation of patients who receive guideline concordant care through needle biopsy. Findings from this study can

assist in the exploration of individual-level factors, specifically tumor characteristics, as predictors of guideline-concordant breast cancer care.

In our study, needle biopsy utilization increased rapidly from 2004-2012, and began to level off from 2013-2015. This research can be used to directly to monitor and benchmark guideline concordance progression through time. The results of this study can also inform future policies an attempt to reduce health disparities among patients with breast cancer by providing the most vulnerable groups with the tools and resources they need to access quality care.

Further Research

Further research should examine the complete association between tumor characteristics and guideline-concordant breast cancer care. While our study explored associations in a few of these characteristics, the exact mechanisms through which tumor characteristics impact guideline concordant care is unknown. Inequalities may drive the differences in effect measures of tumor characteristics in relation to needle biopsy receipt, but having access to individualized patient data regarding income and education could help obtain answers to the knowledge gaps in tumor characteristics as they relate to guideline concordance.

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