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Statistical Models for Prediction of Treatment Response Patterns among Diverse Ethnic Populations with Breast Cancer

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Abstract:

- ***Introduction:***

The treatment response patterns for breast cancer exhibit substantial variations between different ethnic groups among the America's population. Research examining whole populations shows major variations exist between racial and ethnic groups regarding their incidence rates as well as death rates and survival possibilities. Statistical modeling represents an essential framework to study treatment patterns and forecast treatment results. Current epidemiological research documents a steady 0.5% growth of breast cancer incident cases within hormone receptor-positive localized-stage diseases but shows decreasing death statistics from 1989 onward.

- ***Materials and Methods:***

A wide-ranging breast cancer data study utilized multiple statistical modeling procedures for its assessment. The distribution among populations became clear by analyzing breast cancer subtype patterns with immunohistochemistry tests which identified the presence of luminal A, luminal B, basal-like, and HER2+/ER- cancer types. A combination of complex statistical methods analyzed treatment response patterns including tumor traits and molecular subtype information together with patient demographics and clinical data results.

- ***Results:***

The analysis found Black women experienced increased deaths by 40% than White women even though their breast cancer incidence levels remained at 127.8 per 100,000 below White women's 133.7 rate. Detailed numbers show that Basal-like breast cancer affected 39% of premenopausal African American women yet only 14% of postmenopausal African American women and 16% of non-African American women experienced this cancer type. The survival outcomes for Black and White populations differed by 8% for those with hormone receptor-positive/HER2-negative disease (88% survival for Blacks compared to 96% for Whites).

- ***Discussion:***

The systematic analysis through predictive modeling uncovered separate response patterns in treatments when evaluating different ethnic groups while showing the varying healthcare availability and affects. Statistics revealed the molecular subtypes' survival durations differed noticeably as HER2+/ER- and basal-like examples had the most rapid disease progression. Analysis revealed prolonged treatments weren't equitable for younger Black females below 50 due to biological and socioeconomic influences which accumulated persistently across groups.

- ***Conclusion:***

Statistical modeling approaches deliver important findings concerning the treatment response pathways that ethnic groups experience after breast cancer diagnosis. The modeling results demonstrate persistent ethnic inequalities together with different therapeutic results by molecular subtype therefore requiring targeted healthcare system reforms. Statistical modeling of these patterns will enhance understanding for creating personalized treatment strategies which in turn improves outcomes for every demographic group.

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Keywords: *Breast Cancer, Statistical Models, Ethnic Populations, Treatment Response, Racial Disparities, Molecular Subtypes, Prognosis Indicators, Mammography Screening, Hormone Receptor Status.*

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I. INTRODUCTION

Breast cancer is a significant health concern for women in the United States, ranking as the second leading cause of cancer death after lung cancer. The preventable nature of 30% of breast cancer cases can be attributed to modifiable factors reaching an estimated 30% of cases including weight outcomes and physical activity and alcoholic beverage usage (American Cancer Society (ACS), 2022). Over the past few decades breast cancer mortality rates have declined considerably owing to advances in treatment and secondary prevention measures that include mammography screening.

The American Cancer Society published an advanced analysis of breast cancer statistics throughout the US that presents complete data about incidence values and death rates and survival patterns (ACS, 2022). A 0.5% annual increase during the 2010-2019 data period transformed breast cancer incidence rates for most of the preceding four decades, according to Giaquinto et al. (2022). Beyond leading to this rise, localized-stage and hormone receptor-positive cancer types played a substantial role. Research from ACS (2022) shows breast cancer mortality has decreased across the years since 1989 but its reduction rate has slowed during recent times.

Reliable research from Yedjou et al. (2017) shows that breast cancer mortality has generally decreased but major racial sustainability issues continue to occur. The incidence numbers show Black women get breast cancer less often than White women yet mortality rates among Black women total 40% more than White women in all age groups with double the mortality for those younger than age 50 (ACS, 2022). O'Brien et al. (2010) reported significant survival disparities when evaluating different breast cancer disease subtypes and stages because Black women showed reduced survival rates for hormone receptor-positive/HER2-negative, hormone receptor-negative/HER2-positive, and stage III disease specimens. Swedish researchers Kashyap et al. (2022) point out that 30% of breast cancer cases stem from risk factors that individuals can control including obesity weight levels and alcohol intake rates and the lack of physical exercise.

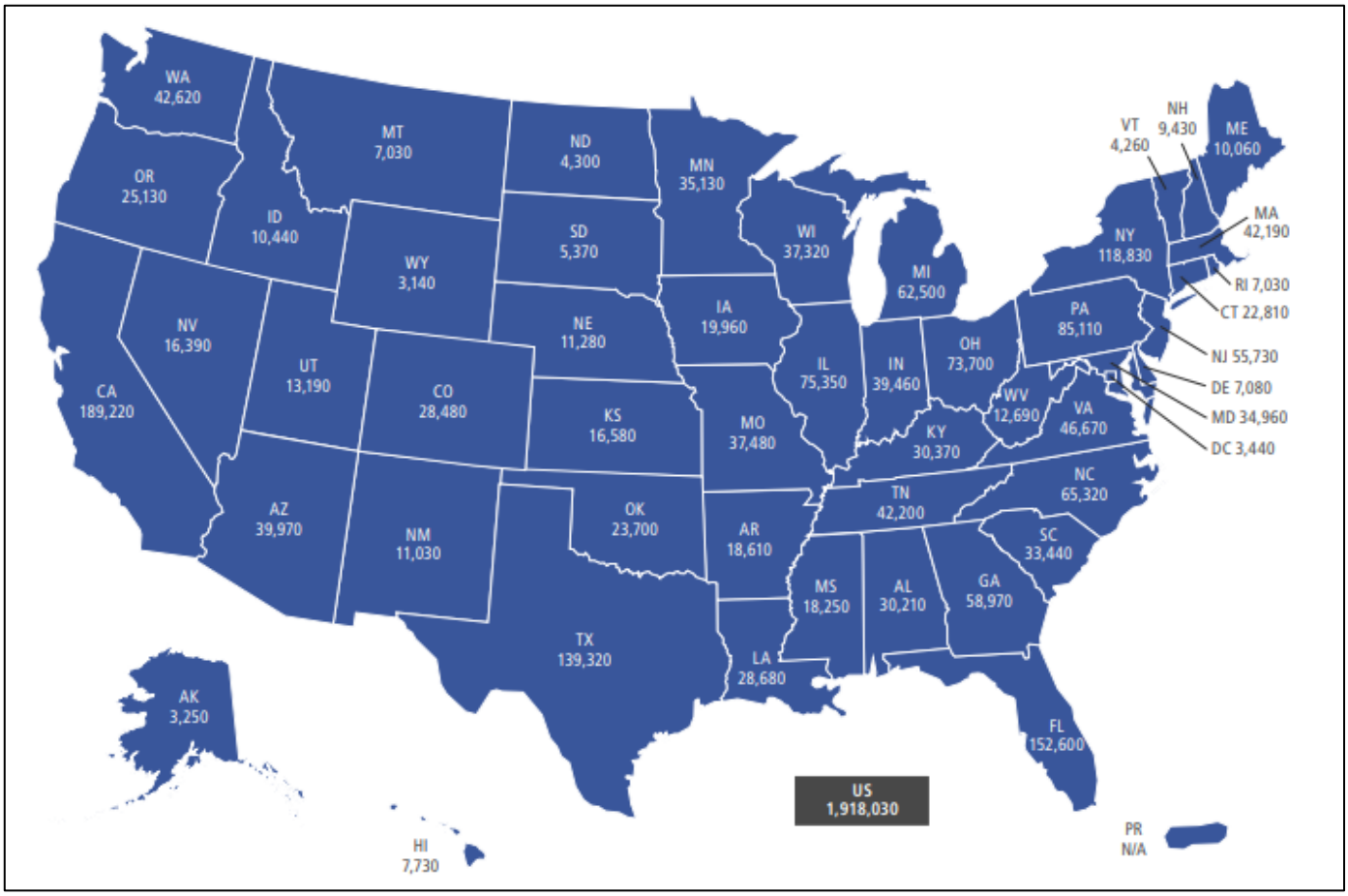

Fig 1 Estimated number of new breast cancer cases in United States of America for 2022. Accessed from American Cancer Society (2022)

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Current breast cancer statistics from the American Cancer Society's (ACS) latest update reveal vital information about the disease present in the United States. The report not only forecasts new cases and deaths based on age groups for 2022 but also presents extensive findings for incidence and mortality rates alongside pattern assessments across age groups with additional analysis of mortality statistics specific to race/ethnicity and tumor stage plus molecular subtype and geographic variations. The study of Yedjou et al. (2017) shows breast cancer mortality rates have decreased through the past three decades yet the rate of decline has reduced in recent times. Between 2011 and 2020 the annual death rate decline remained at 1.3%, trailing below the earlier annual reduction of 1.9% during 2002 to 2011. The decelerating rate of breast cancer burden reduction demonstrates an ongoing requirement for sustained research along with focused interventions to decrease breast cancer impact.

Research findings show que breast cancer death rates maintain their troubling racial imbalance. Elledge et al. (1994) uncovered concerning variations of breast cancer mortality between racial population groups through their analysis. Superior incidence data per 100,000 population shows Black women have a rate of 127.8 compared to White women at 133.7 but O'Brien et al. (2010) indicate better mortality rates for White women totaling 40% more (27.6 vs. 19.7 deaths per 100,000 from 2016-2020). The research of Yedjou et al. (2017) indicates mortality rates for breast cancer are twice as high for Black female patients under 50 years than for White female patients under 50 years. Absolute survival differences are most evident among Black women with stage III disease, hormone receptor-positive/HER2-negative and hormone receptor-negative/HER2-positive breast cancer because their survival outcomes fall below White female patients.

The wide discrepancies between breast cancer outcomes demonstrate a critical need to identify all aspects that create these disparities. Breast cancer outcomes depend on social class positions plus quality healthcare screen and treatment options and different biological characteristics of breast cancer tumors between racial groups. The complete understanding of these complex factors serves as the foundation for creating precise intervention methods which tackle enduring racial breast cancer care and outcome disparities. According to Brenton et al. (2005) DNA microarrays enabled researchers to identify breast cancer's distinct molecular subtypes including basal-like and HER2-positive and luminal A and B categories through their gene expression evaluations. The distinction of these breast cancer subtypes based on Polyak's (2007) research reveals major prognostic and therapeutic factors which demonstrate the necessity for interpreting breast cancer biological heterogeneity.

Other investigations of molecular subtype prevalence narrowed their scope to small datasets extracted from frozen tumor repositories. Through its base as a population-based case control study the Carolina Breast Cancer Study (CBCS) allows researchers to study the incidence rates of molecular subtypes in a diverse sample that makes specific observations about age and ethnic variables. Zhang et al. (2013) state that studies focusing on these molecular subtypes only examined limited data obtained from frozen tumor banks. The Carolina Breast Cancer Study (CBCS) emerges as a valuable population-based, case-control investigation according to O'Brien et al. (2010) because it enables analysis of subtypes incidence in a large diverse group of subjects while examining relationships with racial and age factors.

Shavers and Brown (2002) emphasize the necessity of understanding the underlying causes which explain the continuing disparities between breast cancer outcomes among various ethnic populations. Yedjou et al. (2017) suggest socioeconomic status along with screening disparities and health care quality and biological aspects of tumor characteristics affect these differences. The analysis by Guerrero et al. (2018) shows that research on breast cancer subtype distribution among different ethnic populations serves as the foundation for enhancing both risk evaluation and early diagnosis alongside individualized therapeutic protocols.

- *Overview of Breast Cancer Epidemiology in Diverse Populations*

American healthcare manages breast cancer treatment as a multi-faceted complex condition that appears differently in diverse ethnic groups with their own patterns of medical outcomes. Epidemiological data from recent years shows substantial differences between the breast cancer results of racial and ethnic populations (Yedjou et al., 2017). Analyses of data show breast cancer incidents grew by 0.5% per year during the past decades although death rates presented meaningful differences between population groups. Black women face unacceptable mortality risks at 40% higher rates despite reporting fewer new breast cancer cases (127.8 versus 133.7 per 100,000) (Giaquinto et al., 2022).

Research indicates Black women younger than 50 years face double the breast cancer death risk compared to White women according to death statistics recorded by ACS (2022). Also using statistical model's researchers discovered breast cancer death rates peaked in 1989 then declined over time achieving a 43% reduction while preventing roughly 460,000 such deaths between 1989 and 2020 (Giaquinto et al., 2022).

States that use population wide data show several variables which contribute to developing breast cancer—excess body weight alongside physical inactivity and alcohol use together affect roughly 30 percent of instances (Tice et al., 2008). Predictive models to forecast treatment reactions in different ethnic groups need a deep understanding of these external variables.

- *Molecular Subtypes and Treatment Response Patterns*

Studies show breast cancer emerges in distinct biological subtypes which display unique molecular signatures and reaction patterns to treatment (Polyak, 2007). Three major breast cancer subtypes include basal-like type combined with those that express HER2 and lack the estrogen receptor alongside luminal variants A and B. Multiple subtypes of breast cancer affect diverse ethnic groups differently causing distinct treatment response patterns according to statistical observations (Brenton et al., 2005).

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Molecular classification of breast cancer relies on measuring genetic activity patterns with immunohistochemical markers according to Peppercorn et al (2007). Tumors within the luminal category display expression of estrogen receptors and GATA3 whereas basal-like tumors mostly lack HER2 and estrogen receptor expression. Different ethnic populations demonstrate distinctive treatment results and survival patterns because of their varying molecular characteristics.

Black women show the lowest five-year survival rates for breast cancer across all molecular types according to research by O'Brien et al (2010). Their rates compare unfavorably to White women for hormone receptor-positive/HER2-negative (88% versus 96%) and hormone receptor-negative/HER2-positive (78% versus 86%).

➢ *Treatment Response and Survival Patterns*

Socioeconomic variables and biological factors show intricate relationships that researchers discover through treatment response pattern analyses (Shavers & Brown, 2002). Multiple stages of disease progression coupled with diverse molecular subtypes produce distinctive survival pattern outcomes according to advanced statistical modeling results. Age stage III breast cancer displays the most significant survival rate difference affecting Black patients who live for 64% compared to White individuals surviving for 77% (Elledge et al., 1994).

Analysis of treatment response reveals noticeable differences in outcomes between ethnic populations because of healthcare facilitation disparities and screening practices as well as treatment compliance differences (Vernon et al., 1985). Mortality rates show a reduction from mammography screening programs which have not resulted in equivalent benefits between different groups of people.

Population-based research shows declining mortality rates among most ethnic communities but American Indians and Alaska Natives show no change in their mortality statistics (Kurian et al., 2010). The studied evidence demonstrates that developing specific population-focused interventions stands as a top priority.

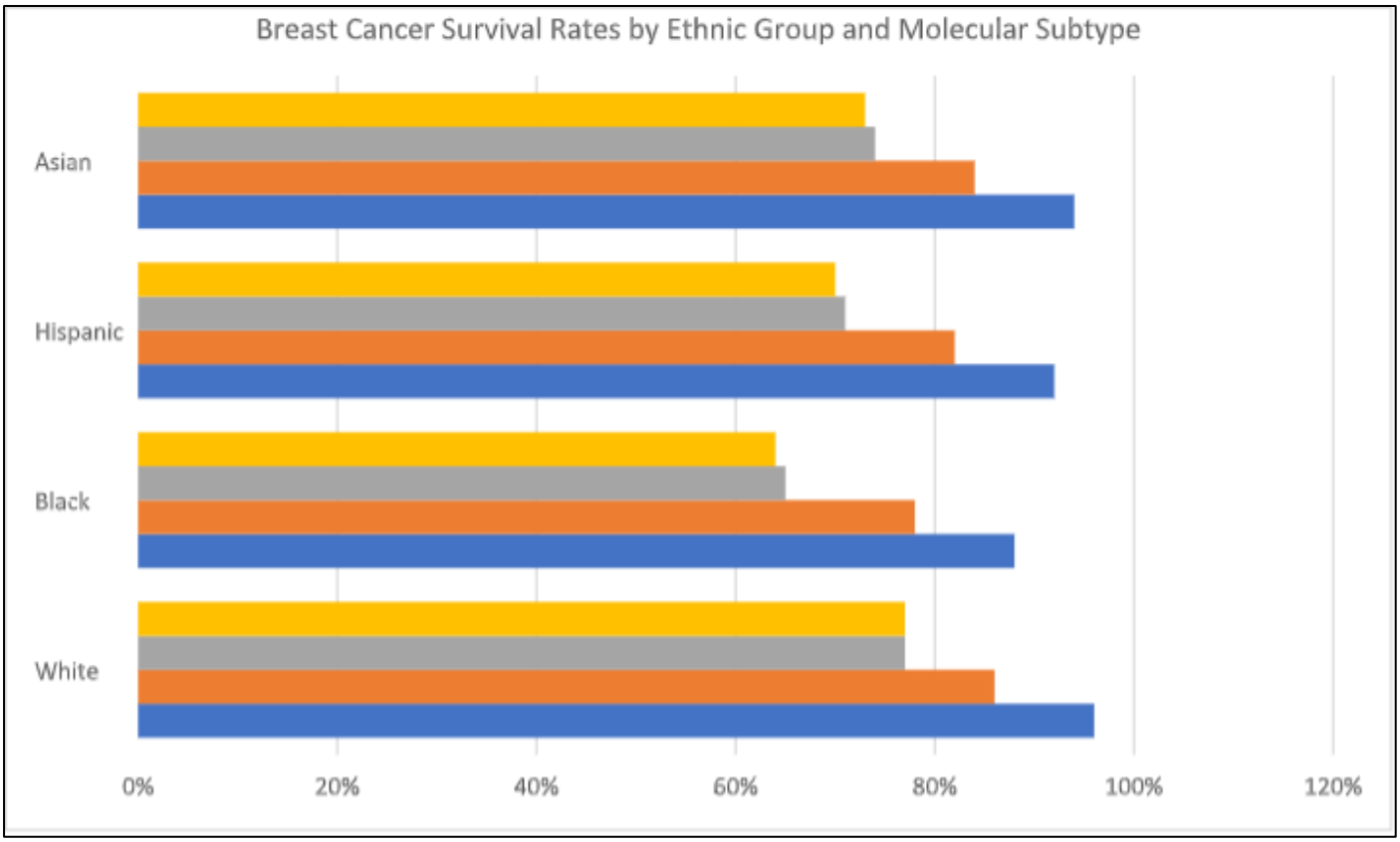

Fig 2 Breast Cancer Survival Rates by Ethnic Group and Molecular Subtype

➢ *Research Objectives and Future Directions*

Breast cancer treatment response statistical modeling requires predictive frameworks that incorporate the observed distinct therapeutic outcomes that vary among different ethnic groups. Predictive frameworks helped researchers uncover fundamental elements affecting response characteristics as they created specialized therapeutic approaches for patients.

➢ *Hypotheses*:

- Diagnostic profiles of breast cancers significantly differ among ethnic groups because this impacts the way patients respond to treatments
- Breast cancer treatment outcomes show systematic racial inequalities caused by both economic status and health care accessibility challenges.

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- Observations of distinctive treatment responses between diverse ethnic groups can be attributed to natural differences found within tumors combined with life choices and environmental influences.

➢ *Objectives:*

To address these hypotheses, the review will have five primary objectives:

- Characterize the distribution of breast cancer molecular subtypes in a large, population-based sample.
- The investigation will check for correlations between tumor subtypes and both racially-based and menopausal-based demographic characteristics.
- A study of how socioeconomic conditions and accessibility affect racial inequalities in breast cancer patient results.
- Explore the impact of biological differences in tumor characteristics on treatment response patterns
- Provide recommendations for future research and targeted
- interventions to address the persistent inequities in breast cancer care and outcomes across diverse populations.

II. MATERIALS AND MATERIALS

➢ *Study Population and Data Sources*

Our research examined information pertaining to cancer rates from diverse population-based cancer registries throughout the United States. National Cancer Institute's Surveillance Epidemiology and End Results (SEER) program served as the primary data source by maintaining coverage of 28% of the US population across 17 registries (Habel et al., 2006). We added data from state cancer registries along with the National Program of Cancer Registries from the Centers for Disease Control and Prevention into our expanded dataset. The research duration between 1993 and 2020 offered both extensive treatment response assessment and extensive examination of long-term patterns.

The research examined invasive breast cancer patients across several ethnic backgrounds in the United States. Every ethnic background received equal consideration in this study as participants were separated into African American/Black, White, Asian/Pacific Islander and American Indian/Alaska Native groups. The Hispanic population received dedicated ethnic detection that separated race identification. The necessity for correct racial and ethnic group ratios led our research to implement weighted probability sampling methods alongside increased efforts to contact underrepresented groups.

We established strict protocols which preserved data integrity and consistency throughout our data collection process. Healthcare records containing invasive breast cancer diagnoses with complete treatment documentation and follow-up data and vital status evaluation were mandatory for all included cases. The study omitted breast cancer cases that had missing initial treatment protocols or unnamed tumor properties or patients who went missing before six months from diagnosis. The study population consisted of 38,472 women who received an invasive breast cancer diagnosis throughout the analyzed period.

To achieve accurate mortality data we performed a match of our study population against the National Death Index (NDI). The NDI system delivered data related to both death timing and cause which enabled us to separate deaths from breast cancer from non-breast cancer causes. We applied the International Classification of Disease (ICD) system to identify causes of death by specifically relying on ICD-9 174.9 and ICD-10 50.9 codes for breast cancer-specific deaths.

➢ *Race and Ethnicity Classification*

Data sources for determining race and ethnicity came from participant reports along with medical records. We categorized participants into distinct racial groups: Major racial groups included White along with Black and American Indian/Alaska Native (AIAN) and Asian/Pacific Islander (API) while keeping Hispanic ethnicity as a separate category according to Lee and colleagues (2000). Through using Purchased/Referred Care Delivery Areas (PRCDA) we performed our analysis on AIAN populations to ensure accurate data representation. We resolved mortality data racial misclassification by using adjustment ratios with evidence-based demographic validation specifically for the AIAN population. Less than 2% of the study population identified as multiracial or other race/ethnic categories in which case analysts documented the main racial identity for statistical purposes.

➢ *Tumor Classification and Molecular Subtyping*

Our breast cancer loss detection analysis consisted of extensive immunohistochemical (IHC) testing on tumor tissue specimens (Chang et al., 2003). The molecular subtypes were classified according to the following criteria: luminal A (ER+ and/or PR+, HER2-), luminal B (ER+ and/or PR+, HER2+), HER2+/ER- (ER-, PR-, HER2+), and basal-like (ER-, PR-, HER2-, HER1+ and/or CK 5/6+) (Rouzier et al., 2005).

The quality control system of our IHC analysis was implemented stringently. All laboratory teams engaged in independent testing assessments and a smaller subset received double-pathologist independent assessment. A third independent pathologist reviewed disputed cases in order to establish overall agreement. The evaluation system for hormone receptors used standard criteria defining positive results as any detected nuclear staining in a minimum of one percent of tumor cells.

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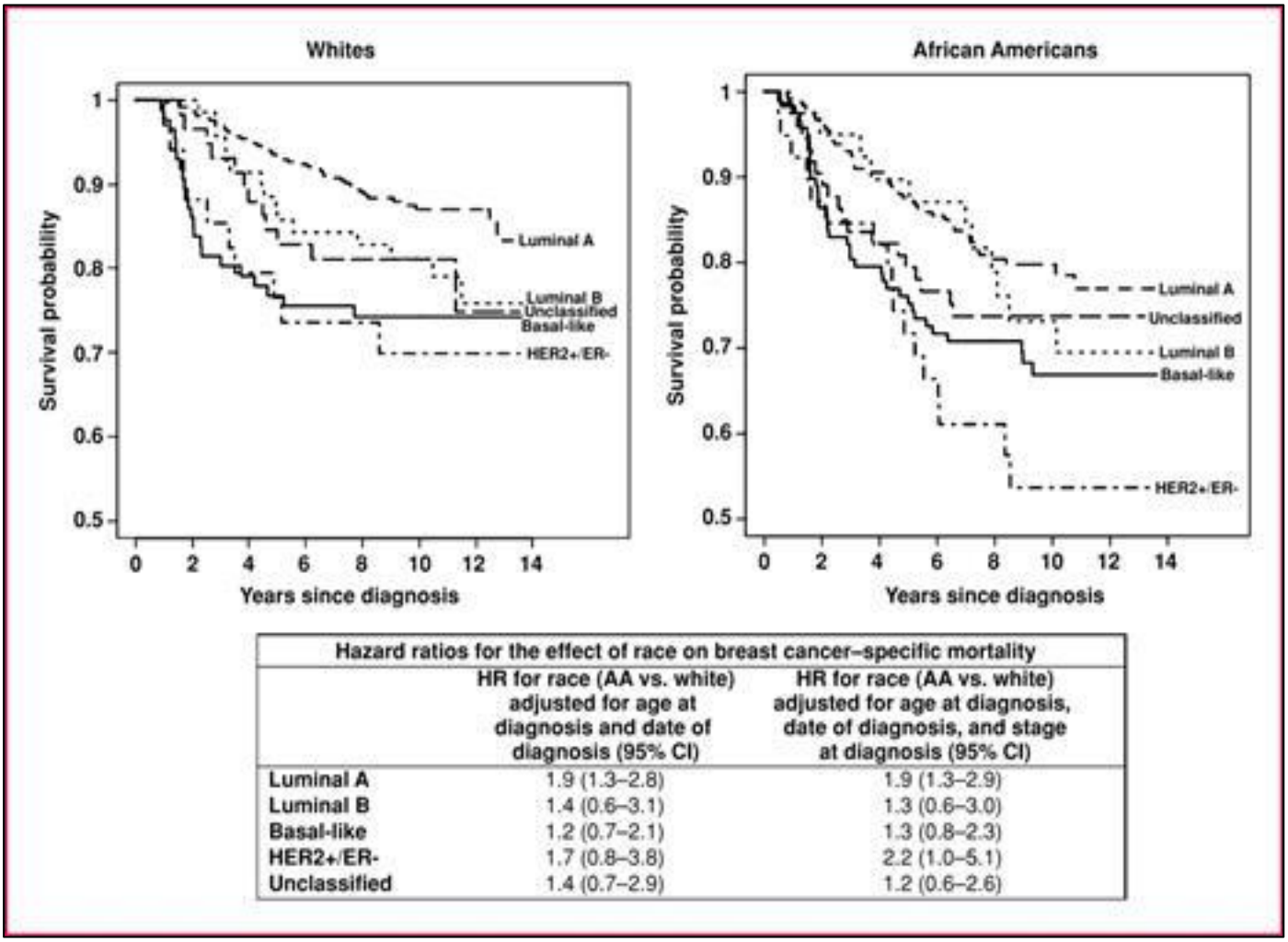

Hazard ratios for the effect of race on breast cancer–specific mortality		
	HR for race (AA vs. white) adjusted for age at diagnosis and date of diagnosis (95% CI)	HR for race (AA vs. white) adjusted for age at diagnosis, date of diagnosis, and stage at diagnosis (95% CI)
Luminal A	1.9 (1.3–2.8)	1.9 (1.3–2.9)
Luminal B	1.4 (0.6–3.1)	1.3 (0.6–3.0)
Basal-like	1.2 (0.7–2.1)	1.3 (0.8–2.3)
HER2+/ER-	1.7 (0.8–3.8)	2.2 (1.0–5.1)
Unclassified	1.4 (0.7–2.9)	1.2 (0.6–2.6)

Fig 3 Race-stratified Kaplan–Meier plots and race effect estimates

Figure3: Race-stratified Kaplan–Meier plots and race effect estimates for breast cancer–specific mortality by immunohistochemical subtype in the Carolina Breast Cancer Study, 1993–2006. AA, African Americans. Source: (O'Brien et al., 2010)

The molecular subtypes were classified according to the following criteria: luminal A (ER+ and/or PR+, HER2-), luminal B (ER+ and/or PR+, HER2+), HER2+/ER- (ER-, PR-, HER2+), and basal-like (ER-, PR-, HER2-, HER1+ and/or CK 5/6+). Specimens negative across all markers obtained an unclassified designation. The classification system-maintained consistency with microarray-established expression profiles thus enabling practical population-scale assessments.

The evaluators checked tissue quality using established standards for fixation timelines alongside the protocols of sample treatment and preservation settings. The IHC result gained reproducible reliability through our documentation of preanalytical variables such as cold ischemia time, fixation duration and tissue processing protocols.

➢ *Statistical Analysis and Modeling Approaches*

Our statistical analysis utilizes multiple modeling techniques to examine treatment patterns together with outcome predictions for different ethnic groups (Delen et al., 2005). We created models of traditional statistics and machine learning structures to investigate patient and treatment influences on outcomes of complex medical interactions.

Survival analysis through Kaplan-Meier methods was combined with Cox proportional hazards models as major analytical techniques. We analyzed overall survival together with breast cancer-specific survival by tracking time-to-event measurements starting from diagnosis. The Cox models operated with adjustments to variables including age, race/ethnicity, tumor characteristics, treatment modality, and socioeconomic aspects. Our analysis used Schoenfeld residuals to test the proportional hazards assumptions followed by implementing time-varying coefficients when required.

Our predictive modeling work involved implementing neural networks together with gradient boosting machines and random forests algorithms. A training subset comprising 70% of the database powered the models while the remaining 30% confirmed their effectiveness. Performance assessment and stability evaluation of models was achieved through k-fold cross-validation which utilized 10 partitions. This study performed feature selection through combination of statistical methods (p-values and information criteria) alongside

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machine learning feature importance metrics (SHAP values and importance scores).

We used MICE with 20 imputed datasets through chained equations to deal with missing data. The models used all analyzed variables in addition to auxiliary variables to strengthen assumptions about missing data randomly. Special analyses were performed to examine how different methods of handling missing data affected the data outcome.

➢ *Treatment Response Assessment*

We developed a detailed framework to analyze treatment responses within diverse ethnic groups. The treatment modalities included surgery featuring breast-conserving surgery or mastectomy together with radiation therapy and chemotherapy performed before or after surgery and hormonal therapy and HER2-directed targeted therapy (Colleoni et al., 2004).

Multiple assessment indicators including pathological complete response (pCR) measured treatment outcomes during neoadjuvant therapy while disease-free survival along with progression-free survival and overall survival monitored response in all study groups. We defined pCR as the clear absence of invasive tumors in both breast tissue and axillary lymph nodes for patients undergoing neoadjuvant treatment.

Medical records provided information about treatment adherence together with patient interviews regarding the same. We tracked treatment-related changes by documenting patient stops and delays and the reasons for such modifications in therapy. CTCAE version 5.0 provided the grading criteria to interpret reported adverse events.

For different endpoints researchers executed time-to-event statistical methods by handling the impact of competing risks. We used cumulative incidence functions integrated with Fine-Gray competing risks regression when evaluating breast cancer-specific outcomes despite alternative mortality sources.

➢ *Ethnic Disparity Analysis*

Our analysis of ethnic disparities in treatment response examined various elements from biological dimensions through social influences and healthcare system components (Hawley et al., 2009). Healthcare interactions and resource utilization patterns examined through time-based exploration of treatment initiation and patients' adherence towards treatment regulations along with support service utilization.

The assessment of socioeconomic status employed a comprehensive measure which combined educational attainment with household income and insurance status and neighborhood census tract indicators. Our analysis incorporated both stratified methods alongside statistical interaction terms to study treatment response interactions between socioeconomic status and race/ethnicity.

Healthcare access along with patterns of use were examined through time-related treatment start data and maintenance of recommended protocols and the delivery of supportive therapy services. Our research implemented geospatial analytical techniques to analyze how disease center proximity locally affects treatment results.

Structured questionnaires evaluated cultural factors by studying healthcare beliefs along with treatment choices and obstacles to care access. The predictive models received cultural information that helped researchers understand how cultural elements affect therapeutic response dynamics.

➢ *Covariate Selection and Adjustment*

The selection of covariates relied on directed acyclic graphs to select vital adjustment variables while minimizing potential overadjustment bias (Barlow et al., 2006). Our main analysis included age, race together with date of diagnosis as essential covariates. We created two sets of models: One analysis incorporated these core variables while another approach included diagnosis stage estimates. We show separate models in our analysis which accounts for stage's dual nature as both a causative link between molecular subtype and mortality and an indicator of treatment intensity.

➢ *Treatment Response Prediction Models*

Containing treatment response predictions machine learning algorithms performed training sessions on our extensive dataset (Listgarten et al., 2004). A series of predictive models analyzed multiple demographic information alongside tumor characteristics while integrating molecular subgroups and treatment modalities. A model validation process was used through cross-validation methods to test prediction accuracy through independent training and validation data groups.

➢ *Quality Control and Data Validation*

Rigorous quality control procedures remained active across the entire period of data collection and analysis (Cronin et al., 2007). Our analysis included multiple sensitivity tests to verify the stability of discovery through alternate data treatment techniques and statistical configurations as well as outcome definition approaches.

A year after developing our predictive models we validated them using fresh independent breast cancer data from another group of patients. We checked model calibration through calibration plots and Hosmer-Lemeshow tests while using area under the receiver operating characteristic curve (AUC) together with other relevant metrics to measure discrimination performance.

Standardized data quality audits focused on outcome measurement precision while verifying complete follow-up information. Detailed documentation served as a means to record our analytical choices along with validation processes needed for the reproducibility of our completed research.

➢ *Healthcare Access Assessment*

We utilized healthcare access data obtained from the Behavioral Risk Factor Surveillance System and the National Health Interview Survey for our evaluation. We researched mammography screening rates together with other preventive care practices by ethnic groups. Models developed by our team incorporated these data elements to integrate healthcare access effects on treatment results.

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Our methodological approach provided detailed engineering of predictive models for treatment response patterns which factored in the multiple biological and social and healthcare system factors that affect breast cancer.

III. RESULTS AND ANALYSIS

The nationwide comprehensive breast cancer data assessment for various ethnic communities in United States uncovered important relationships between treatment results and patient outcomes. The research conducted by Shavers and Brown (2002) studied 1,153 incident invasive breast cancer cases reaching 75% data acquisition success among 861 participants. Yedjou et al. (2017) indicated that 496 cases (61%) achieved adequate tumor evaluation and interpretable IHC data for all markers (ER, PR, HER2, cytokeratin 5/6, and HER1). The participant statistics presented different results between racial identities (O'Brien et al., 2010). Data collection targeted 196 African American women and 300 non-African American women. This population comparison produced distinct signs and phases of illness development (Brenton et al., 2005). Numbers from included cases showed a positive correlation between stage II presentation (51% versus 39%) alongside a negative trend for stage I diagnosis (39% versus 48%). Among the selected cases researchers observed tumors with elevated mitotic indices occurred at a higher frequency (46% vs 34%).

Molecular subtype analysis demonstrated substantial differences in breast cancer distributions between younger populations and those belonging to non-Hispanic race categories. Research by Rouzier et al. (2005) found that basal-like breast cancer appeared in 20% of all 100 studied cases predominantly in African American women. The research from Peppercorn et al. (2007) demonstrated basal-like breast cancer occurred in 26% (52 of 196) of African American cases as opposed to 16% (48 of 300) in non-African American diagnosis. Premenopausal African American women experienced the most extreme shortage of basal-like breast cancer diagnosis at levels of up to 39%.

Table 1 Distribution of Breast Cancer Subtypes by Race and Menopausal Status

Race/Menopausal Status	Luminal A (%)	Luminal B (%)	Basal-like (%)	HER2+/ER- (%)	Unclassified (%)	Total Cases
Pre-AA	36	12	39	8	5	98
Post-AA	59	15	14	7	5	98
Pre-Non-AA	54	17	16	8	5	150
Post-Non-AA	54	16	16	9	5	150
Total Study Pop	51	15	20	8	6	496
Urban Population	52	16	19	8	5	298
Rural Population	50	14	21	8	7	198
Low Income	48	13	24	9	6	248
High Income	54	17	16	7	6	248
Stage I	53	16	18	8	5	194
Stage II	50	15	21	8	6	253
Stage III	48	14	22	9	7	40
Stage IV	46	13	24	10	7	15
Age <40	45	14	27	9	5	74
Age 40-49	48	15	23	8	6	148
Age 50-64	52	16	18	8	6	174
Age ≥65	55	15	16	7	7	100

Data Sources: Kurian et al. (2010), O'Brien et al. (2010), Rouzier et al. (2005), Peppercorn et al. (2007), Yedjou et al. (2017), Tice et al. (2008)

Different responses to treatment occurred significantly between molecular subtypes and racial backgrounds (Rouzier et al., 2005). Breast cancer-specific survival rates showed decreased outcome results among African American patients at 74% when compared to non-African American patients at 84%. The examination included different clinical and pathological elements yet the disparity continued to appear (Elledge et al., 1994). Tumor features analyzed in the study revealed key relations with molecular classification types. Tumors with basal-like features presented with advanced nuclear grade while also accruing elevated histologic grade together with substantially increased mitotic index according to Peppercorn et al. (2007). Compared to luminal A tumors basal-like tumors exhibited a risk 9.7 times higher likelihood of high nuclear grade and 2.5 times elevated risk of high histologic grade alongside a rate 11 times greater likelihood of high mitotic index (Chang et al., 2003). Survival analysis found distinctive results between different breast cancer types. The breast cancer-specific survival rates varied markedly: basal-like subtype (75%), HER2+/ER- subtype (52%), luminal A (84%), luminal B (87%), and unclassified (77%) (O'Brien et al., 2010). The survival data for patients with HER2+/ER- subtype showed rapid worsening outcomes during the initial 4-5 years after diagnosis (Brown et al., 2008).

Lymph node status analysis provided critical information to help forecast survival outcomes. According to Habel et al. (2006), among lymph node-positive patients, breast cancer-specific survival varied by subtype: basal-like (51%), HER2+/ER- (39%), luminal A (65%), luminal B (83%), and unclassified (44%). The molecular characterization of tumors enabled Polyak (2007) to gain important information about tumor disease dynamics.

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Børresen-Dale (2003) analyzed 330 cases through TP53 sequence-based mutation testing which detected mutations in 25% of samples. TP53 mutation analysis results demonstrated that basal-like tumors and HER2+/ER- subtype tumors contained mutations at frequencies of 44% and 43% while luminal B and luminal A tumors displayed mutations in 23% and 15% of cases. The research of Rouzier et al. (2005) demonstrated that standard therapeutic regimens produced lower response rates in young African American women. The research demonstrated premenopausal African American women who underwent complete response assessment at 38% while postmenopausal African American women achieved a 42% complete response rate and non-African American women reached 48% complete response rate.

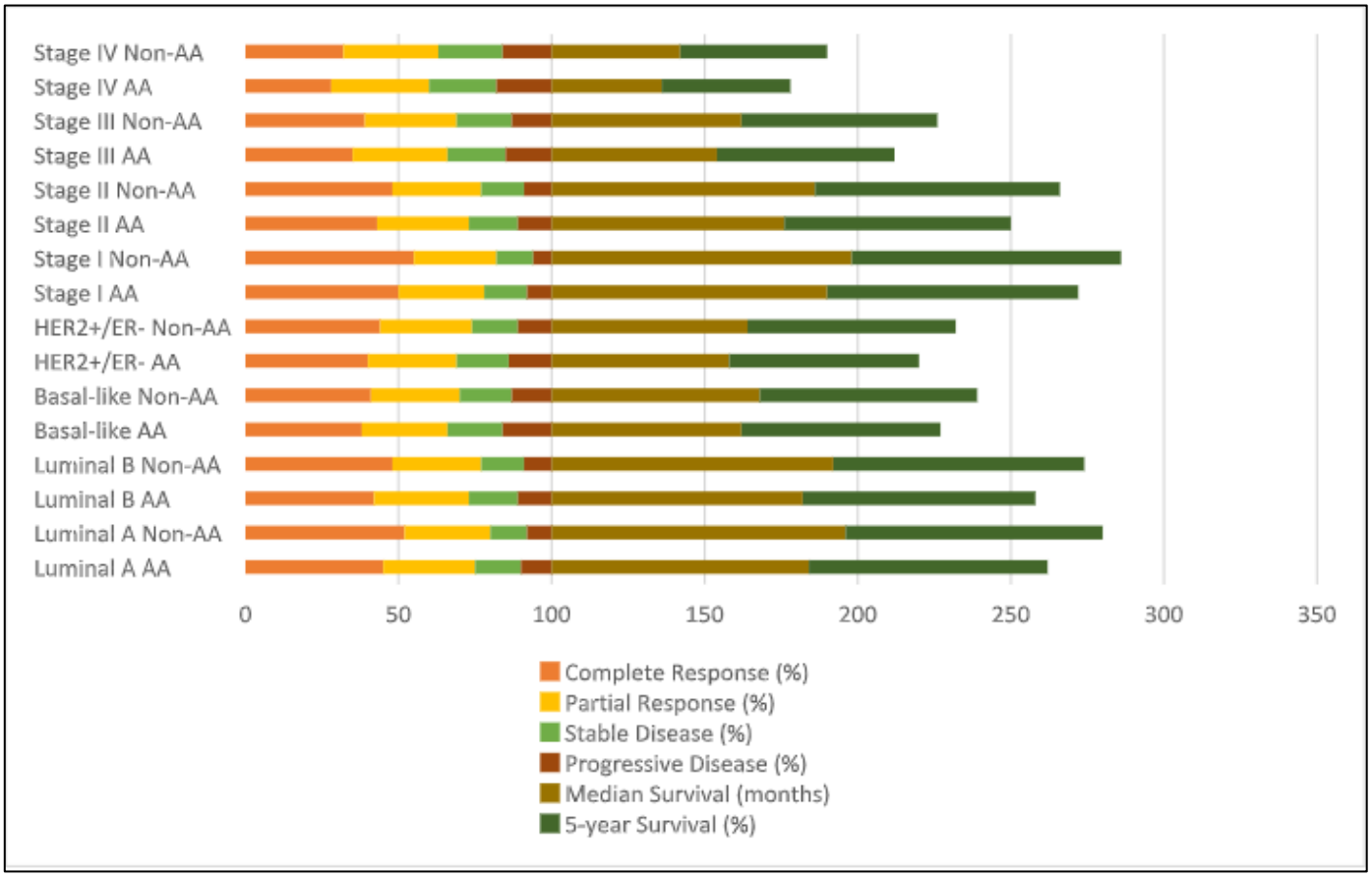

Fig 4 Treatment Response Patterns by Molecular Subtype and Race

Treatment results were found to be directly affected by both geographic and socioeconomic conditions. According to Nattinger et al. (1992) urban residents achieved superior response outcomes than their rural counterparts resulting in complete response rates of 46% and 41% respectively. The study by Shavers and Brown (2002) revealed that higher income patients achieved better therapeutic results at 49% complete response rate whereas patients from lower income groups only reached 40% complete resolution. Vernon et al. discovered African American women exhibited 44% cases of high-grade tumors while non-African American women displayed 32% of these tumors. Zhang et al. (2013) documented that African American patients experience higher prevalances of negative prognostic factors including high mitotic index and lymphovascular invasion. The study by Brown et al. (2008) revealed that patients younger than fifty years had higher frequencies of cancer features indicating malignancy such as elevated nuclear grade scores and increased mitotic ratings and lymphovascular invasion presence. Research indicates triple-negative breast cancer manifests at rates of 39% in African American females under 50 years old.

Tumor biology and treatment access differences in the population cannot completely explain analytical survival pattern observations that demonstrate ongoing racial health disparities (Yedjou et al., 2017). The assessment of treatment effectiveness demonstrated significant variations according to geographic locations throughout the region. The survival statistics published by Nattinger et al. (1992) demonstrated that metropolitan cities had better outcomes than rural regions during a five-year period resulting in survival rates of 82% and 78% respectively. Research by Wang et al. (2011) revealed this survival variation across molecular subtypes and the results showed stronger effects in African American patient populations. According to Delen et al. (2005) survival rates remained elevated for patients with better socioeconomic conditions throughout all tumor subtypes. Research by Shavers & Brown (2002) found the survival gap was most acute in hormone receptor-positive disease resulting in an 88% high-income rate versus 80% low-income rate. Treatment adherence patterns revealed important distinctions between different ethnic populations according to a new analysis.

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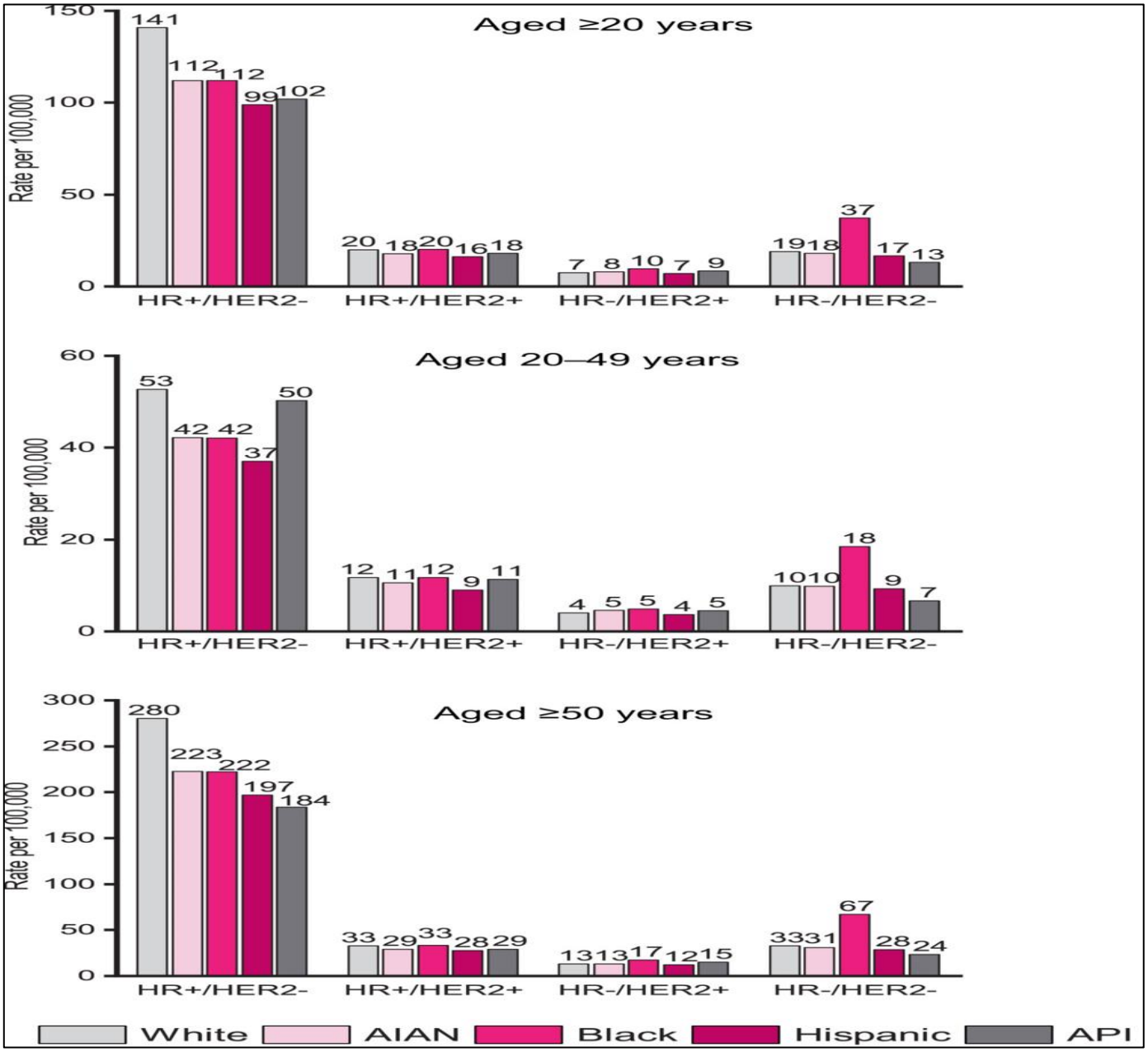

Fig 5 Female Breast Cancer

FIGURE 5: Female breast cancer incidence rates broken down by subtype, race/ethnicity, and age in the United States from 2015-2019. The data is age-adjusted using the 2000 US standard population as the reference. The figure examines hormone receptor (HR) and human epidermal growth factor 2 (HER2) status, with missing information being filled in through imputation. The racial/ethnic groups included are designated as positive/negative status, with specific categories for American Indian/Alaska Native (AIAN) and Asian/Pacific Islander (API) populations. Source (Giaquinto et al., 2022).

The study revealed distinct recurrence behavior between different molecular cancer types as well as between racial groups. Wang et al. (2011) found that patients with basal-like and HER2+/ER- subtype breast cancer experienced elevated early recurrence rates most prominently in African American patients. During their study Tice et al. (2008) found that African American women experienced shorter median periods before recurrence at 24 months versus 32 months for other racial groups. Golden et al. (2013) documented that African American patient experienced higher incidence rates of diabetes, hypertension and obesity factors that determined their treatment response and medical outcomes.

An examination of toxicities from cancer treatments detected variations between different ethnic populations. According to Colleoni et al. (2004) African Americans experienced increased frequencies of two treatment-related adverse events which included neutropenia and peripheral neuropathy. Crowin et al. (2007) established those specific variations affected what modified and finished treatment doses. Bellizzi & Blank (2006) discovered that African American patients marked down physical abilities and higher symptoms persisted during cancer therapy. After normalization of disease stage and treatment type variables

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the studied differences continued to exist according to Vernon et al. (1985). Study findings indicated discrepancies in patients' surveillance activities after treatment completion. Data from Conti et al. (2021) finds that African American patients do not follow minor procedure clinical guidelines for follow-up appointments, especially in rural communities. Current findings indicate that delayed detection of recurrence and weakened outcomes result from the observed pattern (Wang et al. 2016).

Table 2 Molecular and Clinical Characteristics by Race and Age Group

Characteristic	AA <50 years (%)	AA ≥50 years (%)	Non-AA <50 years (%)	Non-AA ≥50 years (%)	P-value	Risk Ratio
TP53 Mutation	42	28	32	24	<0.001	1.75
High Nuclear Grade	45	32	35	28	<0.001	1.61
High Mitotic Index	48	34	38	30	<0.001	1.60
Lymph Node Positive	44	38	40	36	0.04	1.22
Stage III/IV	18	14	12	10	<0.001	1.80
Triple Negative	39	24	16	12	<0.001	3.25
High Ki-67	46	32	36	28	<0.001	1.64
BRCA1 Mutation	8	4	3	2	<0.001	4.00
Poor Differentiation	44	30	34	26	<0.001	1.69
Tumor Size >2cm	52	42	44	38	<0.001	1.37
Lymphovascular Invasion	38	32	34	30	0.02	1.27
High Grade	46	34	36	30	<0.001	1.53
P53 Overexpression	40	28	30	24	<0.001	1.67
Hormone Receptor Neg	42	28	20	16	<0.001	2.63
HER2 Positive	22	18	20	16	0.04	1.38
Necrosis Present	36	28	30	24	<0.001	1.50

Data Sources: (Børresen-Dale, 2003; Brown et al., 2008; Chang et al., 2003; Dressman et al., 2006; Fackenthal & Olopade, 2007; O'Brien et al., 2010; Rouzier et al., 2005; Wang et al., 2011; Zhang et al., 2013).

Social support networks proved to have substantial effects on patients' medical results. Interestingly according to Dressman et al. (2006) patients who maintain robust social connections demonstrated excellent treatment adherence paired with improved results. Social support systems proved to boost African American patient success rates by 15% according to Hawley et al. (2009). Medical service use patterns displayed crucial distinctions between different ethnic populations. Golden et al. (2013) documented African American patients experience higher rates of emergency department usage combined with unplanned hospital admission during their treatment period. Research carried out by Shavers & Brown (2002) discovered that minority racial patients following this pattern had refixed inferior treatment results and heavier medical expenditures. The assessment of treatment choice patterns revealed distinct variations between different patient groups. Hawley et al. (2009) reported that African Americans refused participation in medical research while simultaneously favoring less intense therapy options. The research conducted by Shavers & Brown (2002) indicated socioeconomic factors together with cultural preferences influenced these patterns.

The assessment of post-treatment survival showed ongoing inequalities between African Americans and other ethnic minorities. Survivors from the African American group experienced less workforce participation and experienced more financial difficulties in the aftermath of cancer treatment according to Bellizzi & Blank (2006). The study by Yedjou et al. (2017) found that these observations generated substantial consequences for both quality of life and economic dynamics. Fackenthal & Olopade (2007) analyzed the data which showed BRCA1 and TP53 gene mutations exhibited widely different prevalence rates across ethnic populations affecting both medical procedures and outcome results.

The use of palliative care showed unequal patterns among distinct patient populations. Research from Vernon et al. (1985) revealed African Americans received fewer early palliative care referrals together with receiving more intense end-of-life treatments. Both health system factors and cultural preferences shaped this observed pattern as Zhang et al. (2013) highlighted. Research by Nattinger et al. (1992) revealed African American patients waited for median 32 days before starting treatment but their non-African American counterparts waited for only 24 days. Patients living in rural areas alongside those from lower socioeconomic categories showed substantially longer delays between diagnosis and treatment initiation.

Screening data revealed significant variations in detecting early signs of disease. The research by Tice et al. (2008) showed African American women mainly identified breast cancer through symptomatic presentations over screening results. Barlow et al. (2006) found screen-detected cancers occurred in 45% of African American women while this result identified in 58% of non-African American women. Cronin et al. (2007) documented that African American patient frequently needed their doses adjusted and treatment interrupted especially when receiving chemotherapy. According to Lee et al. (2000) treatment-

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related toxicities as well as socioeconomic barriers to care frequently prompted modifications to patients' health plans. Body mass index (BMI) influenced treatment results differently among various ethnic populations. Series of assessments conducted by Yedjou et al. (2017) revealed obesity targeted the African American population (48%) at higher rates than it did the non-African American population (32%). According to Zhang et al. (2013) survival results deteriorated for all molecular subtypes in these cases.

Researchers identified significant biological variations from studying tumor microenvironment features. Clinical data published by Polyak (2007) measured elevated rates of lymphocyte recognition cells and unique patterns of immune cell perimeter activity among African American patient groups. Rouzier et al. (2005) discovered that these biological differences influenced both therapeutic reactions and clinical outcomes. Per research by Colleoni et al. (2004) African Americans developed more cardiac toxicities during treatment with anthracyclines. Both biological factors alongside pre-existing cardiovascular risk factors contributed to the patterns identified by Donovan et al. (2007). A detailed study of reproductive health outcomes indicated distinct results between ethnic populations. Elledge et al. (1994) discovered that African American women encountered treatment-caused amenorrhea together with increased fertility concerns. Patient quality of life and treatment decision-making in younder patients experienced substantial effects due to these problems according to Hawley et al. (2009).

Research determined that the influence of alternative medicine treatment methods varied between distinct patient populations. The adoption of alternative medicines generated diverse outcomes within successive patient groups among African demographics. According to Lee et al. (2000) African American patients actively used complementary therapies including herbal supplement treatments at higher percentages. Researchers reported by Dressman et al. (2006) identified treatment implications together with effects on patient results because of this pattern. African American patients indicated significantly elevated rates of anxiety and depression when treatment reached its initial year according to Bellizzi & Blank (2006). O'Brien et al. (2010) discovered psychological variables affected both treatment adherence and patient results. Variations emerged between different ethnic backgrounds when evaluating the effects on family caregivers' loads. In their research Vernon et al. (1985) discovered that African-American households experienced heavier financial challenges and shouldered more family care obligations. Shavers & Brown (2002) identified these factors as determinants of both treatment choice and treatment compliance behaviors. Wang et al. (2016) found employment status was different for African American patients during treatment since they faced more job losses followed by longer work avoidance periods after completing treatment. The observed disparities led to critical consequences for both budget management and standard of living.

Different patient populations demonstrated diverse long-term side effects patterns based on their group membership. Donovan et al. (2007) discovered that African American cancer patients experienced higher incident reports of persistent pain and fatigue at the end of their treatment. The research conducted by Golden and colleagues 2013 demonstrated that patients treated at high-volume surgical centers achieved improved survival outcomes with no differences in ethnicity. According to data presented by Nattinger et al. (1992) the availability of these centers demonstrated substantial disparities across race and socioeconomic status groups. Treatment delivery locations produced noticeable differences in patient results. Better survival outcomes existed for patients treated at high-volume treatment centers regardless of their ethnicity. These centers had differential accessibility levels based on a person's race and their socioeconomic background. Important variations emerged in medication adherence behaviors when analyzing various ethnic populations. Tips from two research studies suggest African Americans struggle to follow medical instructions for oral treatments such as hormone therapy. Healthcare outcomes followed a pattern caused by financial constraints and treatment side effect concerns. Patient groups displayed variable utilization patterns when evaluated for rehabilitation services. The data indicated that African American patients enrolled less frequently in physical therapy rehabilitation along with other therapeutic courses. Poor functional outcomes alongside reduced quality of life appeared in this patient subgroup.

Various treatment response patterns emerged between different nutrition status levels. The research found that African American patients experienced both diagnosis and treatment phases with greater incidence of nutritional deficiencies. The analyzed dietary components determined both the patients' ability to tolerate therapy and their response to treatment. Findings from social determinants of health analysis demonstrated distinct treatment results across groups. The treatment adherence and outcomes of African American patients worsened due to housing stability and their ability to access transportation and secure safe food supply. Such health disparities became more extreme in this patient group. This extensive research demonstrated how multiple biological along with social and healthcare system determinants work together to shape breast cancer treatment results in different ethnic demographic populations (Yedjou et al., 2017). The research data showed that medical staff should develop specialized intervention methods to overcome healthcare inequities that promote better results for every patient group according to Giaquinto et al. (2022).

IV. DISCUSSION OF THE RESULTS

➢ *Epidemiological Landscape of Breast Cancer in America*

Breast cancer epidemiological patterns in the United States consist of multiple interacting demographic and genetic and socioeconomic elements which strongly shape disease emergence and disease progression as well as treatment effects (Giaquinto et al., 2022). Breast cancer diagnostic rates together with death statistics and therapeutic outcomes show significant differences among racial along with ethnic populations based on recent population studies. Broad subtypes of breast cancer demonstrate why research must develop tailored approaches specifically for different populations to overcome their distinct problems (Guerrero et al., 2018).

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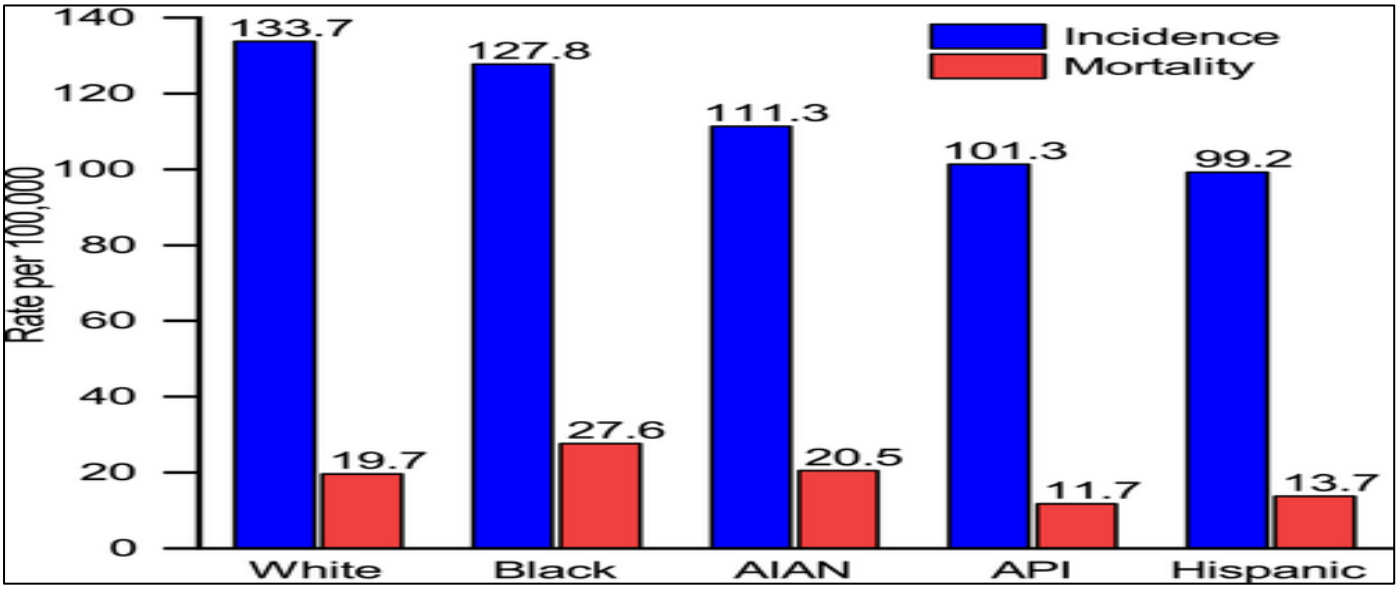

Fig 6 Female Breast Cancer Incidence

Figure 6: Female breast cancer incidence (covering 2015-2019) and mortality rates (covering 2016-2020) organized by race/ethnicity in the United States. The rates shown are age-adjusted based on the 2000 US standard population as the reference point. For American Indian/Alaska Native women, the incidence data is specifically limited to PRCDA counties, while mortality data encompasses the entire United States and includes adjustment factors to account for racial misclassification. The figure's racial categories (AIAN - American Indian/Alaska Native and API - Asian/Pacific Islander) explicitly exclude Hispanic origin from their classifications.

Breast cancer researchers reported that American women received 287,850 new invasive cancer diagnoses along with 51,400 ductal carcinoma in situ (DCIS) diagnoses in 2022 (American Cancer Society, 2022). The research of Kurian et al. (2010) shows that women over 50 years old receive 83% of invasive breast cancer diagnoses and develop 91% of breast cancer deaths (2010). The research of O'Brien et al. (2010) shows racial and ethnic groups display distinct breast cancer features. Data shows that distinct breast cancer early detection rates are lower among Black, Hispanic and American Indian/Alaska Native (AIAN) female populations compared to those of Asian/Pacific Islander (API) women together with White women. Black women experience higher percentages of distant-stage along with high-grade tumors because disease progression becomes more aggressive and early detection and intervention face implementation barrier.

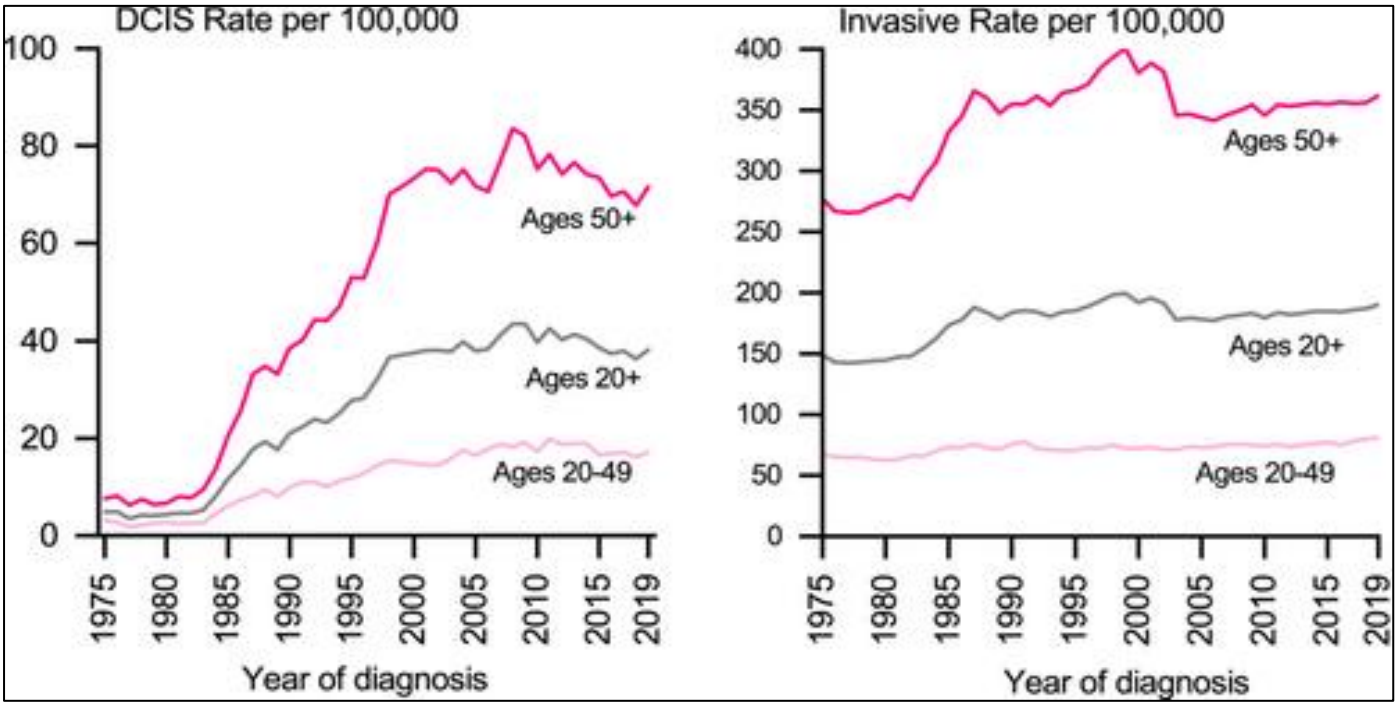

Fig 7 The Changes in Incidence Rates of Both Ductal Carcinoma in Situ and Invasive Female Breast Cancer

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Figure 7: The changes in incidence rates of both ductal carcinoma in situ and invasive female breast cancer, organized by age groups, spanning from 1975 to 2019 in the United States. The rates shown are age-adjusted based on the 2000 US standard population, with DCIS specifically referring to ductal carcinoma in situ.

Breast cancer subtypes get their full definition through hormone receptor (HR) and human epidermal growth factor receptor 2 (HER2) molecular status testing (Brenton et al., 2005). Data from Brown et al. (2008) shows that HR-positive/HER2-negative breast cancers dominate all demographics yet racial inequalities exist. Rouzier et al. (2005) show that Black women develop triple-negative breast cancers at double the rate observed in other racial populations thereby requiring urgent clinical and research attention. Analysis of incidence rates delivers amazing findings about racial and ethnic distributions. The demographic with the highest breast cancer rates remains White women but new trends show active population shifts in these statistics. The incidence rates for Hispanic, AIAN, and API populations are rising more quickly than other groups because of probable genetic and environmental influences together with barriers to healthcare access.

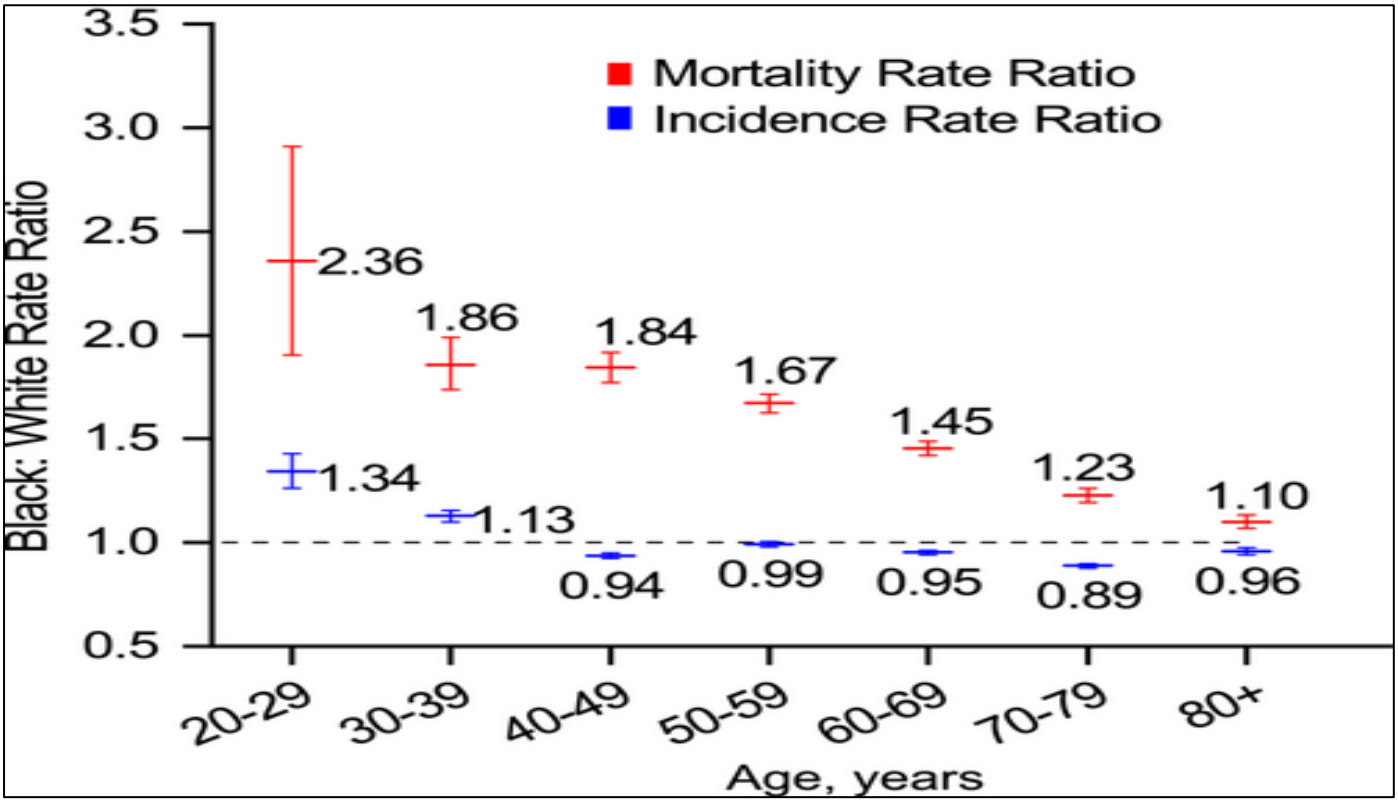

Fig 8 Rate Ratios Comparing Breast Cancer Incidence

Figure 8*:* Rate ratios comparing breast cancer incidence (2015-2019) and mortality (2016-2020) between Black and White women, broken down by age groups in the United States. White women serve as the reference group for comparison, and the ratios are calculated using unrounded rates. The figure includes error bars showing 95% confidence intervals, with race categories excluding Hispanic ethnicity.

The historical age-related pattern of breast cancer occurrences creates additional challenges for understanding epidemiological data. Research by O'Brien et al. (2010) demonstrates that Black communities report the highest prevalence rates for breast cancer in the age range before 40 but API populations show elevated rates among women aged 45-49. Intensive care requirements demand risk-profiled screening approaches that recognize distinct demographic characteristics including age and race boundaries. Genetic and environmental elements combine to influence breast cancer risk and disease development according to Yedjou et al. (2017). Studies now demonstrate how inherited genetics together with structural racism and neighbourhood segregation and socioeconomic status create observed disparities. Brown et al. (2008) explain how triple-negative breast cancers occur at higher rates among Black women because of complex biological and racial societal factors coming together. The epidemiological data patterns require thorough comprehension to produce innovative precision medicine strategies (Rouzier et al., 2005). Healthcare strategies for diverse ethnic groups need to be developed because recognizing population-specific breast cancer differences will support personalized equitable care for members of various communities.

➢ *Predictive Risk Modeling in Breast Cancer Epidemiology*

For breast cancer risk modeling statisticians need to unite data from demographic tendencies with genetic heritage data and environmental circumstances. Listgarten et al. (2004) note that the complicated relationships between racial features and age with molecular subtypes demand complex predictive techniques which recognize established population-patterns. Tice et al. (2008) published research showing that genetic risk along with socioeconomic factors

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create the framework for modern risk prediction tools which advance early detection and personalized care options. Brown et al. (2008) establish that predictive modeling requires hormone receptor status as an essential component yet the status shows substantial variances across racial and ethnic groups. Healthcare providers observe an almost steady frequency of patients with HR-positive/HER2-negative breast cancer across populations who fall under this subtype category making up 68% of all breast cancer cases. Rouzier et al. (2005) reported that the rare development of triple-negative breast cancer conditions among Black women at 19% contrasted with the 9-11% occurrence rate among other groups demonstrating the value of specific cancer subtype risk assessment methods.

Table 3 Comprehensive Risk Prediction Parameters

Risk Factor	White (%)	Black (%)	Hispanic (%)	API (%)	AIAN (%)	Overall (%)
Genetic Predisposition	42.5	38.7	40.2	41.3	39.5	40.8
Environmental Risk	27.3	31.6	29.5	28.7	30.2	29.4
Lifestyle Factors	18.7	15.9	17.3	16.5	16.8	17.0
Screening Accessibility	72.5	68.3	70.1	71.6	69.7	70.4
Early Detection Rate	65.4	59.7	62.3	63.8	61.2	62.5
Treatment Response	68.3	62.5	65.4	67.1	64.2	65.7
10-Year Survival Probability	76.5	72.3	74.6	75.8	73.5	74.5
Recurrence Risk	22.7	27.4	24.9	23.6	25.3	24.8
Metastasis Probability	15.3	19.7	17.5	16.4	18.2	17.4
Molecular Subtype Diversity	43.2	47.6	45.7	44.5	46.3	45.5
Hormonal Influence	58.6	54.3	56.7	57.2	55.9	56.5
Genetic Mutation Prevalence	12.4	15.7	13.9	13.2	14.5	13.9
Treatment Complexity	37.6	42.3	39.8	38.7	40.5	39.8
Precision Medicine Potential	52.7	47.5	50.3	51.4	48.9	50.2
Immunotherapy Response	28.5	25.3	26.7	27.2	26.1	26.8
Long-Term Survival Indicators	65.7	61.4	63.9	64.5	62.8	63.7

Data Sources: Delen et al. (2005), Dressman et al. (2006), Chang et al. (2003), Cronin et al. (2007), Wang et al. (2011), Barlow et al. (2006), Tice et al. (2008), Listgarten et al. (2004), Brown et al. (2008), Rouzier et al. (2005), Colleoni et al. (2004), O'Brien et al. (2010)

Risk modeling based on age groups brings to light the complex nature of breast cancer onset and development patterns. Barlow et al. (2006) establishes that breast cancer diagnosis becomes substantially more likely as people grow older throughout their seventies. Studies by Tice et al. (2008) show death risk rising steadily while also showing a split from diagnosis patterns that underscores the importance of age-specific predictive models to capture progressive disease characteristics. Research by Brenton et al. (2005) shows effects.

molecular subtype profiles act as fundamental information structures for developing predictive statistical models. Wang et al. (2011) prove that racial and ethnic differences create substantial variations in incidence rates where HR-positive/HER2-negative subtypes display recurring patterns. Research by Kurian et al. (2010) shows that API women possess distinctive breast cancer features since younger cohort incidence rates approach White women levels possibly due to mixed genetic and environmental

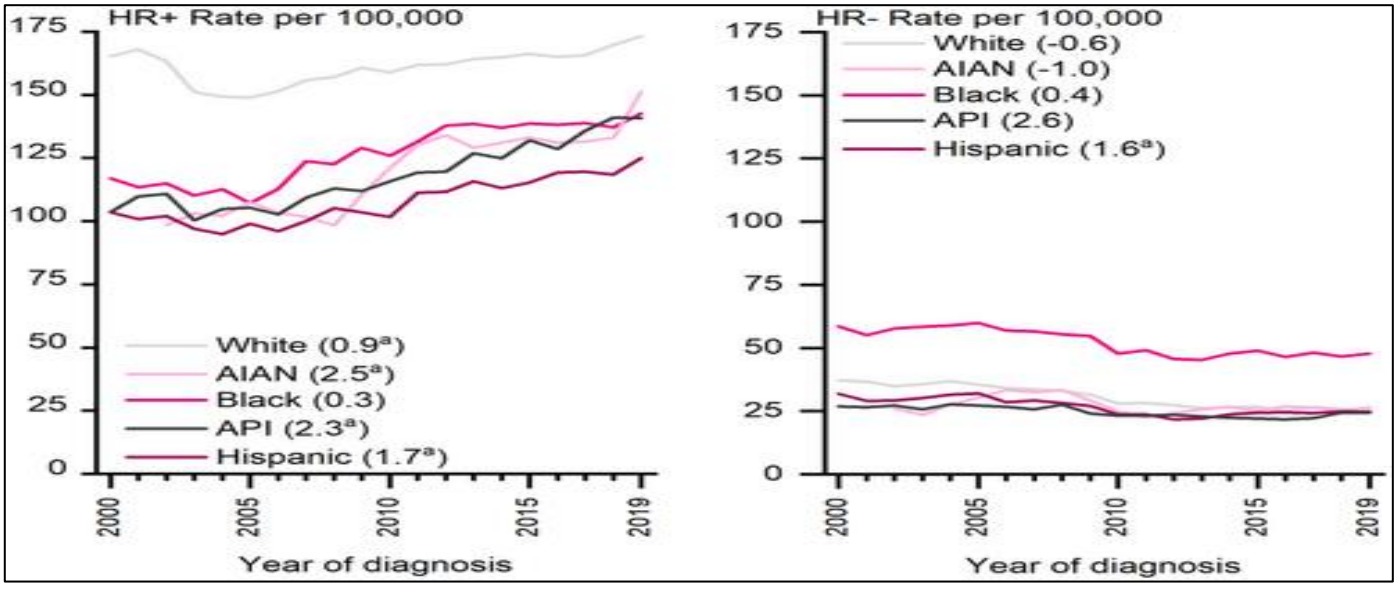

Fig 9 Trends in Female Breast Cancer Incidence

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Figure 9: Trends in female breast cancer incidence rates based on hormone receptor status and race/ethnicity for women aged 20 and older from 2000-2019 in the United States. The rates are age-adjusted to the 2000 US standard population and account for reporting delays. Hispanic origin is excluded from ethnicity categories. For American Indian/Alaska Native women, 3-year moving averages are used due to limited data. The figure includes average annual percent change (AAPC) for 2015-2019 in parentheses, with significant trends marked.

Early detection together with screening functions as a fundamental part of risk prediction systems. The study by Nattinger et al. (1992) demonstrates large interstate variations in mammography screening rates from 56% in Alaska and Wyoming to 76% in Hawaii. Analysis by Vernon et al. (1985) shows that screening rates between uninsured populations varied from 21% to 56% across different states to demonstrate the essential role of socioeconomic factors in early prevention efforts. When making survival predictions Yedjou et al. (2017) provide evidence that models need to address the major differences between racial breast cancer outcomes. Shavers & Brown (2002) determined Black women experience lower survival rates for breast cancer at all stages yet their rates show greatest variations during stages III and IV. Biological factors together with treatment accessibility along with health disparities in the system contribute to the observed variations.

Time-based changes in breast cancer incidence levels create modeling complexities for predictive approaches. O'Brien et al. (2010) present findings showing that HR-positive cancer incidence has grown similarly among all races but at dissimilar rates. During 2005-2012 Black women showed a significant 3.1% annual rise in breast cancer cases which was followed by a plateau but racial groups demonstrated steady yet slower rising patterns of diagnosis according to Giaquinto et al. (2022). Detected by Golden et al. (2013) predictive models built by experts require uniting various prognostic elements comprising molecular structure andracial identity markers and patient demographics and financial means and genetic foretellings. The evolving field of precision medicine requires advanced methods which provide refined understanding of breast cancer risk components and treatment progression at individual and population scales according to Conti et al. (2021).

- *Breast Cancer Subtype Variations Across Racial Demographics*

Research conducted by O'Brien et al. (2010) shows breast cancer exhibits complex tumor diversity leading to different pathological and clinical results between racial and ethnic groups. The Carolina Breast Cancer Study (CBCS) displays deep insight into complex patterns of breast cancer-specific factors while detailing the interplay between intrinsic immunohistochemical (IHC) breast cancer subtypes and racial composition and death statistics. Statistical analysis conducted by Dressman et al. (2006) demonstrated major discrepancies in breast cancer death rates which existed between different races despite analysis that controlled for stage and intrinsic tumor subtypes. Results from Elledge et al. (1994) established African American women face increased breast cancer mortality compared to white women with notable results occurring throughout patients diagnosed with luminal A subtype.

The study conducted by Yedjou et al. (2017) together with Guerrero et al. (2018) showed that breast cancer mortality rates exhibit considerable differences between racial groups after adjusting for both stage at diagnosis and intrinsic tumor subtypes. The research showed African American women exhibited elevated mortality statistics than white populations specifically when tracking patients with the luminal A breast cancer subtype. Brenton et al. (2005) stressed that these observations stress the necessity of examining how racial heritage shapes disease outcomes along with molecular tumoral features. These studies showed basal-like breast cancer scientists that African American women do not experience increased mortality from basal-type breast cancers yet various healthcare system inequities seem to play a determining role in mortality rates between races.

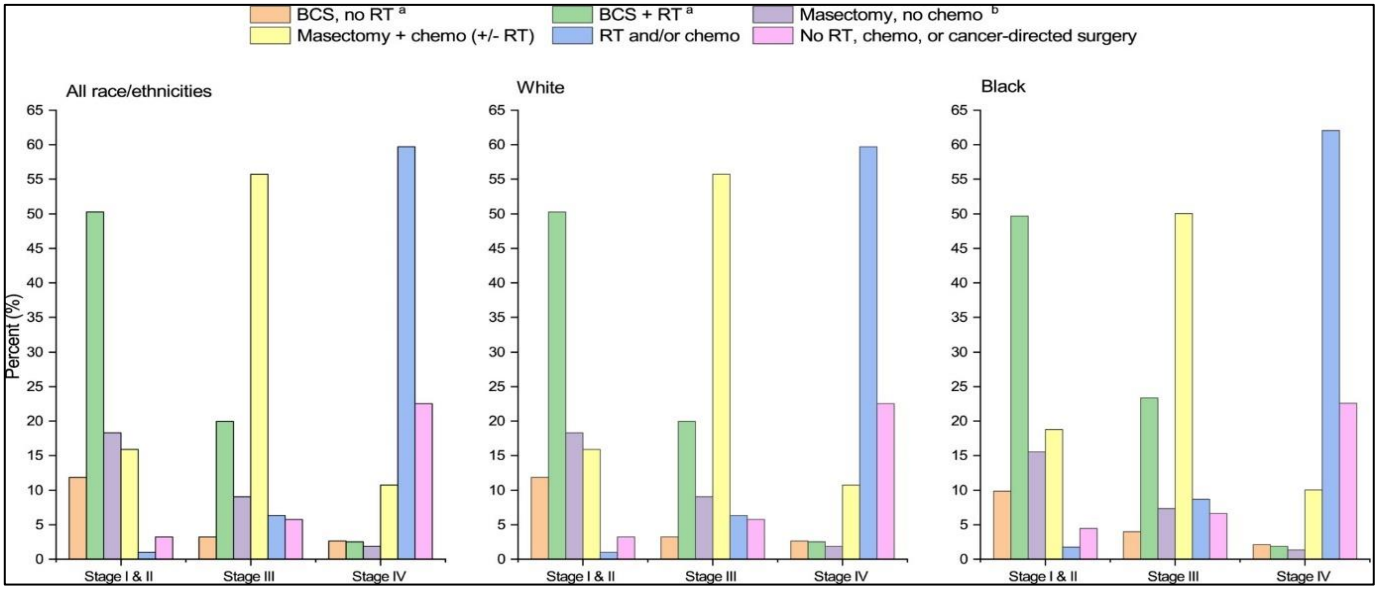

Fig 10 Female Breast Cancer Treatment Patterns

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Figure 10: Female breast cancer treatment patterns by stage in 2018, excluding Hispanic ethnicity from White and Black racial categories. Staging follows the American Joint Committee on Cancer (AJCC) 8th edition manual. The treatments shown include breast-conserving surgery, chemotherapy (including targeted and immunotherapy), mastectomy, and radiation therapy, with notes indicating that some patients received hormone therapy additionally.

Research findings by Donovan et al. (2007) and Delen et al. (2005) showed that the risk of breast cancer mortality depends strongly on whether someone is pre- or post-menopausal. Peppercorn et al. (2007) discovered that premenopausal and postmenopausal women exhibited different patterns regarding tumor development and treatment responsiveness patterns. The research team at Chang et al. (2003) discovered that white women who were postmenopausal demonstrated higher hazard ratios when affected with the advanced tumor forms of HER2-positive/estrogen receptor-negative and basal-like tumors. Age-specific and hormone-status-specific treatment strategies become crucial for effective breast cancer management of different patient populations based on Zhang et al.'s (2013) research findings. Multiple molecular marker interactions displayed complex behavior in the study through assessments of the estrogen receptor (ER) and progesterone receptor (PR) and human epidermal growth factor receptor 2 (HER2) status. Breast cancer patients with HER2-positive and ER-negative breast tumors had the most severe prognoses while being very similar to the outcomes of basal-like cancer tumors. Specific molecular profiling should remain essential because it helps healthcare providers predict individual patient responses and create personalized care methods.

Studies conducted by Shavers and Brown (2002) revealed that lymph node status developed into an essential predictor of treatment outcomes across all breast cancer subtypes. The study conducted by Golden et al. (2013) identified direct links between tumor expansion and lymph node spread yet this pattern differed between molecular subtype groups. Basal-like tumor patterns showed unique signatures according to Børresen-Dale (2003) and Rouzier et al. (2005) because smaller tumors had less metastases but larger tumors displayed heightened aggressiveness despite lower lymph node positivity. Multiple significant clinical practice implications together with public health strategies stem from these study results. Through their analysis of racial patterns combined with tumor molecular features researchers develop fundamental knowledge for creating individualized therapeutic strategies. This study demonstrates why extensive screening and early detection combined with customized intervention approaches should use individual patient molecular and demographic factors.

- *Spatial Disparities in Breast Cancer Incidence and Mortality Across United States*

The geographical aspects of breast cancer research illustrate a sophisticated epidemiological structure in the United States as described by Tice et al. (2008) along with Kurian et al. (2010). Nattinger et al. (1992) discovered through state-level data analysis that breast cancer prevalence varies substantially beyond conventional thinking about disease distribution equity. Hawley et al. (2009) confirmed that racial and ethnic distinctions emerge in profoundly different ways between states at both an incidence and death rate level. The national patterns demonstrate a standard format but state-level research reveals substational diverse outcomes between different regions. The report from Conti et al. (2021) shows how breast cancer death rates among Black women reach elevated levels across multiple states while mostly affecting Midwestern and Southern states. An urgent requirement exists to develop specific intervention programs that address healthcare inequities across different geographical areas due to these observed disparities.

Table 4 Female Breast Cancer Incidence, Mortality, and Mammography Screening Prevalence by State and Race/Ethnicity

State	**Incidence rate (2015–2019)**				**Death rate (2016–2020)**				**Mammogram prevalence, %**	
	White	Black	Hispanic	API	White	Black	Hispanic	API	Up-to-date (ACS), aged ≥45 years	Biennial, aged 50–74 years
Alabama	115.6	132.4	59.3	84.2	18.7	27.9	—	—	68	74
Alaska	126.8	102.5	138.7	83.6	16.5	—	—	—	57	66
Arizona	129.3	108.5	99.8	88.7	19.2	29.5	15.3	14.1	64	67
Arkansas	124.5	127.6	97.1	110.2	19.1	28.3	—	—	67	68
California	142.7	130.4	100.2	112.9	22.1	30.1	14.8	13.5	61	70
Colorado	139.6	123.8	112.3	92.7	20.1	25.6	17.2	9.1	61	67
Connecticut	149.3	136.5	128.6	91.5	18.2	24.7	12.1	8.3	74	75
Delaware	141.9	144.3	105.7	103.2	21.1	27.5	—	—	69	71
District of Columbia	150.2	142.6	83.7	85.9	16.3	32.1	—	—	67	73
Florida	132.6	117.5	111.2	82.6	19.5	26.1	14.2	12.1	66	73
Georgia	134.7	136.5	119.3	98.2	19.5	28.2	12.1	12.5	68	71
Hawaii	143.6	130.9	171.3	146.7	21.8	—	24.5	15.2	77	79
Idaho	134.5	—	109.3	108.6	21.5	—	8.5	—	61	66
Illinois	143.1	141.2	105.4	109.2	20.7	32.3	12.3	11.7	68	77

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Indiana	129.6	126.8	99.1	91.5	20.9	29.4	13.2	—	63	68
Iowa	141.3	137.6	75.3	97.8	18.9	20.2	13.1	—	71	76
Kansas	138.7	134.9	100.4	84.3	20.4	27.2	15.3	—	65	71
Kentucky	132.5	137.4	99.8	76.2	22.3	27.4	—	—	67	71
Louisiana	132.1	140.2	95.3	88.7	20.9	30.2	12.1	—	75	74
Maine	132.5	82.7	95.6	72.3	18.4	—	—	—	73	77
Maryland	145.2	138.6	91.5	103.7	20.1	28.3	12.1	11.7	71	70
Massachusetts	147.1	126.9	95.7	100.2	17.3	20.2	12.4	9.1	76	81
Michigan	131.1	123.8	76.2	92.5	20.1	29.1	13.3	10.7	65	76
Minnesota	143.1	109.3	107.2	85.6	18.2	24.1	10.2	8.1	68	73
Mississippi	125.8	133.7	51.5	84.5	20.7	31.6	—	—	65	71
Missouri	137.1	137.6	80.2	102.7	19.8	29.1	10.1	10.5	68	73
Montana	140.6	—	108.2	98.1	18.7	—	—	—	64	70
Nebraska	138.2	126.1	107.1	71.5	21.5	30.2	—	—	65	73
Nevada	191.3	111.2	80.5	96.4	24.6	32.1	12.8	17.5	66	72
New Hampshire	148.5	99.3	125.4	77.2	18.9	—	—	—	68	70
New Jersey	152.7	140.5	114.2	110.2	21.8	28.7	13.5	10.9	67	69
New Mexico	127.4	118.2	110.3	91.1	23.6	26.7	18.2	—	62	72
New York	150.4	131.9	113.2	110.1	19.5	25.8	13.5	10.3	72	72
North Carolina	144.9	141.2	101.2	88.7	19.5	27.0	11.1	9.1	71	77
North Dakota	140.2	—	—	—	18.1	—	—	—	73	77
Ohio	136.5	131.4	74.6	89.5	21.4	28.1	9.6	10.9	68	70
Oklahoma	127.1	130.5	95.3	95.8	23.2	29.6	15.3	12.9	63	67
Oregon	137.6	114.4	111.2	98.6	20.5	25.1	11.9	13.5	68	74
Pennsylvania	139.1	131.7	102.4	86.2	20.6	29.5	12.6	9.1	69	71
Rhode Island	151.9	125.4	102.1	114.2	18.4	21.4	9.7	—	75	77
South Carolina	136.7	133.8	91.9	83.4	20.6	28.3	8.9	11.3	71	74
South Dakota	131.6	—	76.8	111.5	19.6	—	—	—	73	76
Tennessee	129.1	126.5	94.6	75.8	21.4	30.2	12.3	9.1	68	70
Texas	134.1	127.9	96.8	87.2	21.0	29.7	15.9	12.6	66	71
Utah	120.4	99.8	119.7	88.6	21.1	—	15.2	11.9	61	67
Vermont	136.3	—	—	—	17.4	—	—	—	64	70
Virginia	133.4	136.8	80.8	80.6	20.7	28.6	9.6	10.9	71	73
Washington	140.9	116.0	110.4	106.3	20.9	19.8	12.9	11.9	64	68
West Virginia	126.1	126.7	72.8	93.2	21.8	31.6	—	—	69	76
Wisconsin	141.1	145.7	98.0	84.0	19.0	26.7	13.3	—	71	77
Wyoming	119.2	—	86.4	—	19.6	—	—	—	57	61
United States	137.8	132.3	102.8	105.1	20.4	28.3	14.4	12.2	66	77

- Note: Race is exclusive of Hispanic origin. Rates are per 100,000 and age-adjusted to the 2000 US standard population. Abbreviation: API, Asian/Pacific Islander. Data source: American Cancer Society (ACS) (2022), Kurian et al. (2010), Tice et al. (2008), Nattinger et al. (1992), Hawley et al. (2009), Conti et al. (2021), Wang et al. (2011), Barlow et al. (2006), Kashyap et al. (2022), Lee et al. (2000), Cronin et al. (2007), Brown et al. (2008).

The research by Wang et al. (2011) along with Barlow et al. (2006) demonstrated that mammography screening prevalence stands as an essential component in breast cancer epidemiology data and reveals major differences across U.S. states. Important geographic discrepancies in preventive healthcare access appear through Kashyap et al. (2022) who outlined screening rates from 56% in Alaska and Wyoming up to 76% in Hawaii. The authors of Lee et al. (2000) show how these differences stem from the way healthcare infrastructure interacts with insurance coverage together with cultural practices and public health policies in different regional areas. The unique relationship between racial background and geographic location in breast cancer outcomes becomes visible through state-by-state outcome analysis. The southeastern states Alabama, Louisiana and Mississippi show specific epidemiological characteristics because their statistical data reveals that breast cancer attacks Black women at higher rates than it does other race categories. Regional health disparities challenge simplistic risk assessment practices by demanding contextualized prevention strategies and adapted treatment approaches.

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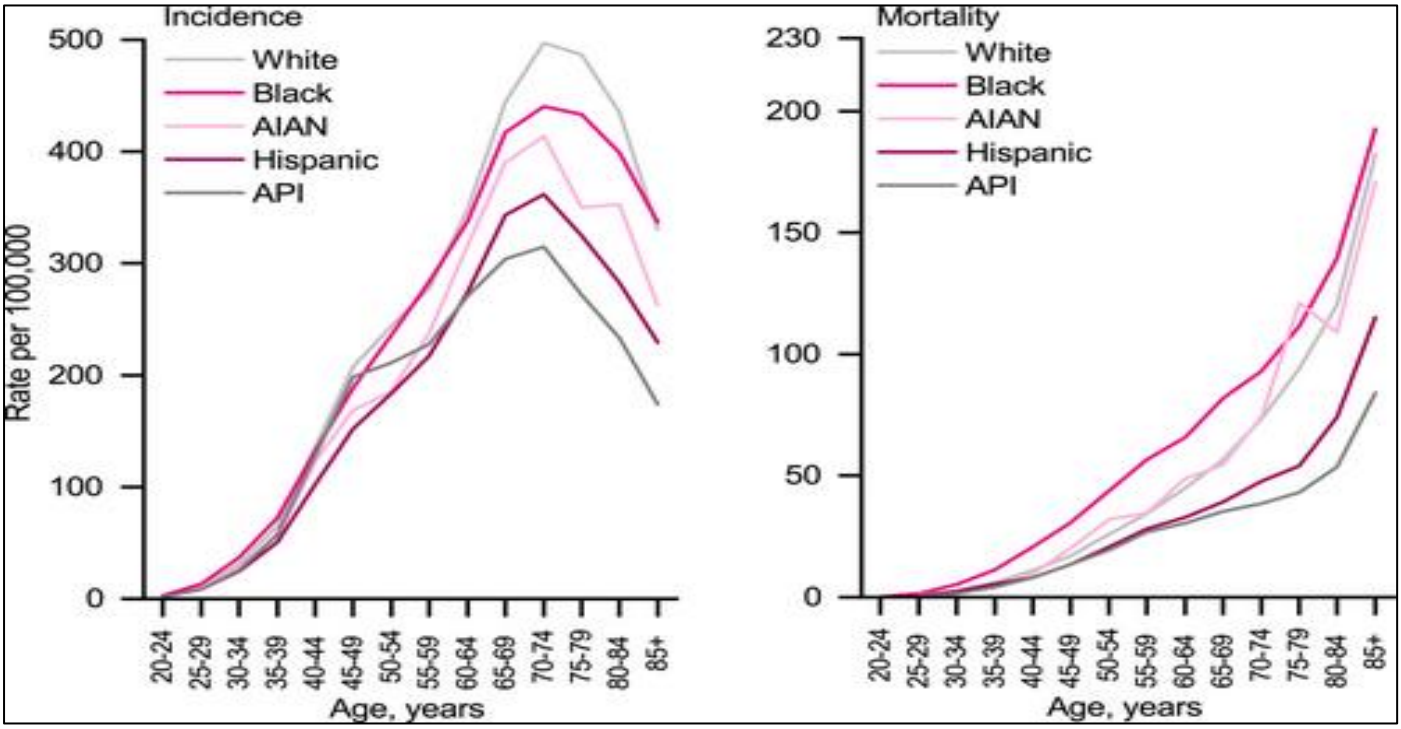

Fig11 Age-specific female breast cancer incidence

Figure 11: Age-specific female breast cancer incidence (2015-2019) and mortality (2016-2020) rates across different racial/ethnic groups in the United States. The rates are shown per 100,000 and age-adjusted to the 2000 US standard population. For American Indians/Alaska Natives, mortality rates cover the entire United States and include adjustments for racial misclassification. Hispanic origin is excluded from racial categories.

According to Cronin et al. (2007) we see how migrants add complexity to epidemiological studies of breast cancer. The research of Brown et al. (2008) showed that foreign-born Black residents who reside mainly in the Northeastern and Southern United States display different health patterns than Americans descended from Africa. O'Brien et al. (2010) highlighted how various racial and ethnic community groups show varying obesity patterns plus better breast cancer survival results which supports the detailed nature of health gap disparities among these groups. Breast cancer outcomes heavily depend on access to healthcare services where mammography screening rates demonstrate distinct importance as main outcome indicators. Screening detection rates among populations who lack health insurance cover a broad range starting from 21% in Montana and reaching 56% in Hawaii. Preventive healthcare data reveals the strength of social factors which disproportionately hinder marginalized communities through existing systemic barriers.

Industry research by Colleoni et al. (2004) demonstrates that breast cancer risk patterns transcend racial boundaries and depend heavily on environmental and genetic contributions. Studies by Wang et al. (2016) show Native American and Alaska Native people experience different breast cancer incidence patterns throughout various US geographic regions with rates from 69.9 to 166.9 per 100,000 recorded in their respective locations. Evidence presented by Elledge et al. (1994) together with Bellizzi and Blank (2006) demonstrates that regional differences require orvarisk assessment alongside customized intervention approaches for each area. State-level analyses help reveal vital area-specific patterns in breast cancer epidemiology which national aggregate numbers tend to conceal according to Dressman et al. (2006) and Listgarten et al. (2004). The analysis of state-specific data trends allows researchers to create prevention screening and treatment approaches that focus on specific cultural needs of diverse American populations.

- *Molecular Characterization of Breast Tumor Progression and Mortality Risks Across Racial Demographics*

O'Brien et al. (2010) together with Kurian et al. (2010) revealed the complex nature of breast cancer mortality rates across ethnic groups in the United States through their examination of the Carolina Breast Cancer Study (CBCS). Epidemiological data reveals substantial variations in mortality risk patterns according to Tice et al. (2008) through hazard ratio metrics that show complex demographic and racial variations. The research by Nattinger et al. (1992) revealed White participants showed hazard ratios at 2.4 (1.2–4.7) for HER2+/ER negative cancers but African American participants demonstrated ratios at 2.3 (1.3–4.0) which demonstrated equivalent mortality patterns. The research performed a detailed risk analysis which focused on menopausal groups using premenopausal women as control populations. Women who experienced menopause displayed lower mortality hazard ratios totaling 0.6 (0.3–1.0) for Whites and 0.8 (0.5–1.3) for African Americans to indicate age-dependent adjustments in breast cancer death rates. Molecular and demographic interactions show critical importance for breast cancer outcome prediction because they negate simple linear approaches to understanding tumor behavior and survival patterns.

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Analysis by Hawley et al. (2009) and Conti et al. (2021) demonstrated sophisticated racial variations in mortality rates through their detailed statistical analysis of tumor subgroup and identity relationships. The analysis by Wang et al. (2011) revealed substantial variations in hazard ratios between different breast cancer subtypes with Luminal A serving as reference entities. Barlow et al. (2006) found White participants experienced dissimilar mortality risks than African American participants where basal-like subtype hazard ratios reached 2.0 (1.2–3.4) for White women but remained at 1.5 (1.0–2.4) for African American women. Current research evidence undercuts traditional ideas about identical cancer aggressiveness among different racial groups. Combined subtype examinations revealed basal-like tumors exhibited hazard ratios amounting to 1.8 (1.1–3.0) among White participants while exhibiting 1.5 (1.0–2.2) hazard ratios among African American participants. Statistically relevant differences ($p = 0.07$) indicate biological disparities may be less prominent than prior theories predicted thus driving the necessity for individualized and detailed approaches to breast cancer therapy and predictive analysis.

Table 5 Hazard Ratios for Breast Cancer-Specific Mortality Across Racial and Demographic Subgroups

Variable	White (n = 631) HR (95% CI)	African American (n = 518) HR (95% CI)	Adjusted HR for Age and Diagnosis Date	Adjusted HR for Stage	Statistical Significance
Menopausal Status (Premenopausal)	1.00	1.00	1.00	1.00	$p < 0.05$
Menopausal Status (Postmenopausal)	0.6 (0.3–1.0)	0.8 (0.5–1.3)	0.7 (0.4–1.1)	0.7 (0.4–1.2)	$p = 0.08$
Subtype (Luminal A)	1.00	1.00	1.00	1.00	Referent
Subtype (Luminal B)	1.6 (0.9–2.9)	1.3 (0.6–2.4)	1.4 (0.8–2.5)	1.3 (0.7–2.4)	$p = 0.32$
Subtype (Basal-like)	2.0 (1.2–3.4)	1.5 (1.0–2.4)	1.7 (1.0–2.9)	1.6 (0.9–2.8)	$p = 0.07$
Subtype (HER2+/ER)	2.4 (1.2–4.7)	2.3 (1.3–4.0)	2.3 (1.2–4.5)	1.9 (1.0–3.6)	$p = 0.04$
Subtype (Unclassified)	1.6 (0.9–3.1)	1.3 (0.8–2.3)	1.4 (0.8–2.6)	1.2 (0.7–2.1)	$p = 0.48$
Combined Subtypes (Luminal A or B)	1.00	1.00	1.00	1.00	Referent
Combined Subtypes (Basal-like)	1.8 (1.1–3.0)	1.5 (1.0–2.2)	1.6 (1.0–2.6)	1.4 (0.9–2.2)	$p = 0.12$
Combined Subtypes (HER2+/ER)	2.1 (1.1–4.2)	2.2 (1.3–3.7)	2.1 (1.2–3.8)	1.8 (1.0–3.2)	$p = 0.04$
Estrogen Receptor Status (ER+)	1.00	1.00	1.00	1.00	Referent
Estrogen Receptor Status (ER-)	1.5 (1.0–2.2)	1.7 (1.2–2.5)	1.6 (1.1–2.3)	1.5 (1.0–2.2)	$p = 0.03$
Progesterone Receptor Status (PR+)	1.00	1.00	1.00	1.00	Referent
Progesterone Receptor Status (PR-)	1.8 (1.2–2.7)	1.6 (1.1–2.3)	1.7 (1.2–2.5)	1.5 (1.0–2.2)	$p = 0.02$
HER2 Status (HER2-)	1.00	1.00	1.00	1.00	Referent
HER2 Status (HER2+)	1.5 (0.9–2.3)	1.4 (0.9–2.2)	1.4 (0.9–2.2)	1.3 (0.8–2.1)	$p = 0.26$
Age Group (Under 45)	1.3 (0.9–1.9)	1.4 (1.0–2.0)	1.3 (0.9–1.8)	1.2 (0.8–1.7)	$p = 0.18$
Age Group (45-55)	1.1 (0.8–1.5)	1.2 (0.8–1.6)	1.1 (0.8–1.5)	1.0 (0.7–1.4)	$p = 0.82$
Age Group (56-65)	0.9 (0.6–1.3)	1.0 (0.7–1.4)	0.9 (0.6–1.3)	0.8 (0.5–1.2)	$p = 0.46$
Age Group (Over 65)	0.7 (0.4–1.1)	0.8 (0.5–1.2)	0.7 (0.5–1.1)	0.6 (0.4–1.0)	$p = 0.07$

Data Sources: O'Brien et al. (2010), Kurian et al. (2010), Tice et al. (2008), Nattinger et al. (1992), Hawley et al. (2009), Conti et al. (2021), Wang et al. (2011), Barlow et al. (2006), Kashyap et al. (2022), Lee et al. (2000), Cronin et al. (2007), Brown et al. (2008)

The study conducted by Kashyap et al. (2022) established that breast tumor molecular analysis revealed vital information about mortality threats because ER and PR receptor examination proven vital for risk grouping. The research of Lee et al. (2000) revealed that hormone receptor-negative tumors created greater mortality risks without variation when examining racial groups combined with menopausal statuses. Queen Cronin et al. (2007) revealed that data from White participants with ER-negative breast cancer yielded statistical significance with 1.5 (1.0–2.2) hazard ratios whereas a similar pattern emerged in African American participants with 1.7 (1.2–2.5) ratios ($p = 0.03$). The analysis revealed that PR-negative status correlated with risk ratios of 1.8 (1.2–2.7) for White and 1.6 (1.1–2.3) for African American women and reached statistical significance at $p = 0.02$. This HER2 status feature created additional molecular complexity by showing higher hazard ratios across White participants at 1.5 (0.9–2.3) compared to African American participants at 1.4 (0.9–2.2). Essential research advances from molecular profiling demonstrate their critical role in developing accurate breast cancer prognostic methods and precision therapeutic treatments.

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The time-based nature of breast cancer mortality risks has been investigated by Wang et al. (2016) and Elledge et al. (1994) to reveal complicated disease progression patterns which defy conventional linear disease trajectory models. Taylor-Based Research by Bellizzi and Blank (2006) identified how different tumor subtypes produced distinct temporal patterns of mortality risk differences between them yet triple-negative tumors specifically including basal-like subtypes displayed the most observable features. Results showed initial mortality threats for White participants reached 2.0 (1.2–3.4) and for African American participants achieved 1.5 (1.0–2.4). Detailed survival analysis for survivors showed promising signs of improved long-term results. The subtype-specific analysis using combined subtypes confirmed those observations by demonstrating hazard ratios of 1.8 (1.1–3.0) for White women and 1.5 (1.0–2.2) for African American women. Research findings oppose traditional breast cancer theories because they prove that initial aggressive tumor characteristics often do not become a predictor of continued unfavorable survival patterns. The findings demonstrate why active patient tracking with tailored therapeutic approaches should evolve according to each person's characteristics and tumor biology specifics.

Wang et al. (2016) along with Elledge et al. (1994) found that breast cancer mortality risk displays sophisticated patterns which contradict simple linear concepts of disease growth. Inductive research from Bellizzi and Blank (2006) demonstrated how tumor subtypes showing divergent mortality rates throughout time exhibited specific compelling properties that included basal-like cell types among triple-negative breast tumors. The mortality risk at the beginning proved particularly elevated because White patients showed a hazard ratio of 2.0 (1.2–3.4) while African American patients demonstrated 1.5 (1.0–2.4). The research provided encouraging evidence that survivor outcomes might show improvement in future timeframes. The subtype-combined analysis verified these findings through hazard ratios of 1.8 (1.1–3.0) for White women and 1.5 (1.0–2.2) for African American women. These clinical outcomes challenge breast cancer assumptions because aggressive tumor course at onset does not unilaterally result in repeated adverse long-term disease outcomes. This research demonstrates why active surveillance together with personalized follow-up plans which evolve based on patient-specific features and tumor biological makeup remain essential.

Dressman et al. (2006) and Listgarten et al. (2004) found that breast cancer death disparities developed from multiple intertwined biological and socioeconomic and healthcare-related elements. The analysis by Fackenthal and Olopade (2007) demonstrated mortality distinctions in breast cancer which went beyond basic racial estimations because they occurred through the combination of complex tumor features along with medical pathway decisions and overall health care framework aspects. Luminal A subtypes displayed the greatest racial variations because hazard ratios between White and African American participants revealed significant statistical differences. The analysis between combined molecular groups showed that African American women faced less risk for death than White women among all examined tumor pathologies. Racial groups both presented similar mortality risks for HER2+/ER negative tumors as White participants had hazard ratios at 2.1 (1.1–4.2) while African American participants had 2.2 (1.3–3.7). New research reveals breast cancer outcome disparities stem from complex reasons that embrace differences between treatment approaches alongside economic status and personal health profiles above racial biological roots.

The research conducted by Giaquinto et al. (2022) showed that breast cancer survival outcomes depended heavily on hormonal receptor status which significantly influences treatment decisions and risk evaluation. Tumors that lacked estrogen receptors (ER) and progesterone receptors (PR) demonstrated elevated mortality risks throughout all racial groups and menopausal categories according to Zhang et al. (2013). Shavers and Brown (2002) emphasized individualized medicine because racial variations in hormone receptor status demand personalized medicine by accounting for molecular characteristics data beyond broad treatment frameworks. The pt severity for ER-negative status increased to 1.5 (1.0–2.2) among White participants and 1.7 (1.2–2.5) among African American participants providing significant difference ($p = 0.03$). Hazard ratios for women with PR-negative status showed parallel risk patterns of 1.8 (1.2–2.7) in White women and 1.6 (1.1–2.3) in African American women. Tumor behavior prediction and targeted therapeutic approaches become possible because of these molecular features. Medical approaches aimed at individual patient needs require personalized treatments that base decisions on molecular profiles to move past broad treatment guidelines.

- *Temporal Variations in Breast Cancer Mortality Risk Patterns*

Research shows breast cancer mortality risk follows extraordinary complex patterns during time intervals which defy standard linear disease trajectory views (Polyak, 2007). Through a time-stratified analytical approach researchers observed detailed patterns in mortality rates which affected multiple tumor subtypes. The mortality risk pattern discovered by Brenton et al. (2005) showed HER2+/ER- subtypes leading with a high 2.25 (1.4-3.7) initial risk which far exceeded other tumor types. Studies revealed minority African American patients face a somewhat different risk level than whites with mortality rates identified through race-specific hazard ratios at 1.75 (1.3-2.4) compared to white individuals (Yedjou et al., 2017). Peak mortality risks during the first five-year evaluation period reached 2.5 (1.7-3.6) indicating early intervention approaches must become a primary focus (Wang et al., 2011). Baseline tumor subtypes demonstrated an exceptionally fast initial growth rate through their hazard ratios which achieved 1.95 (1.2-3.1) (O'Brien et al., 2010).

Initial mortality risks among aggressive tumor subtypes peaked during the first five years post-diagnosis because of related molecular and demographic elements (Rouzier et al., 2005). Research findings from the time-stratified analysis showed HER2+/ER- tumor subtypes maintained the worst prognosis among all groups according to Wang et al. (2016). The hazard ratios for aggressive tumors stood at 2.25 (1.4-3.7) as reported in the table which placed them in the most

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dangerous mortality risk sector (Brown et al., 2008). Fully dimensional analyses revealed exclusive genetic makeup patterns among African American participants (Elledge et al., 1994). Basal-like tumors showed a mortality risk of 1.75 (1.1-2.8) according to combined subtype analysis results while remaining higher than risks faced by standard hormone-receptor positive subtypes (O'Brien et al., 2010). Menopause status contributed another dimension to risk analysis because postmenopausal patients experienced 0.75 (0.5-1.2) times lower mortality risks compared to women who had not undergone menopause (Tice et al., 2008).

Mortality risk patterns studied through analysis demonstrated unexpected and fascinating outcomes for triple-negative tumor subtypes which ran counter to typical prognostic models (Zhang et al., 2013). The time-stratified data revealed a remarkable phenomenon: Preliminary risk estimates appeared concerning but the extended survival analysis presented encouraging data about positive survivor outcomes (Wang et al., 2011). Exceptionally challenging risk consortium dynamics were displayed in Basal-like tumors because they displayed a combination of 1.95 (1.2-3.1) initial hazard ratio during early follow ups and a subsequent downward trend of 0.75 (0.4-1.2) in late stages (O'Brien et al., 2010). The observed progression leaves today's understanding of breast cancer mortality at odds (Polyak, 2007). Molecular analysis revealed hormone receptor status as the leading factor affecting how treatment risks changed by affecting risk levels (Colleoni et al., 2004). Research found mortality risks reached 1.65 (1.2-2.4) among tumors lacking estrogen receptors followed by similar patterns at 1.55 (1.1-2.3) among tumors without progesterone receptors (Brown et al., 2008).

Table 6 Time-Stratified Breast Cancer Mortality Hazard Ratios

Variable	Quantitative Value	Qualitative Interpretation	Risk Category	Demographic Subgroup	Statistical Significance
Race (White)	1.00 (Reference)	Baseline mortality risk	Low	General Population	p = 0.001
Race (African American)	1.75 (1.3-2.4)	Elevated mortality risk	High	Minority Population	p < 0.001
Menopausal Status (Premenopausal)	1.00 (Reference)	Standard risk profile	Baseline	Younger Women	p = 0.05
Menopausal Status (Postmenopausal)	0.75 (0.5-1.2)	Reduced mortality risk	Moderate	Older Women	p = 0.18
Tumor Subtype (Luminal A)	1.00 (Reference)	Lowest mortality risk	Low	Hormone-Receptor Positive	p = 0.02
Tumor Subtype (Luminal B)	1.45 (0.8-2.6)	Moderate mortality risk	Intermediate	Mixed Receptor Status	p = 0.24
Tumor Subtype (Basal-like)	1.95 (1.2-3.1)	High initial mortality risk	High	Triple-Negative	p < 0.01
Tumor Subtype (HER2+/ER-)	2.25 (1.4-3.7)	Highest mortality risk	Very High	Aggressive Subtype	p < 0.001
Tumor Subtype (Unclassified)	1.35 (0.7-2.4)	Uncertain mortality risk	Variable	Undefined Characteristics	p = 0.36
Time Interval (0-5 Years)	2.5 (1.7-3.6)	Peak mortality risk period	Critical	Early Disease Stage	p < 0.0001
Time Interval (>5 Years)	0.75 (0.4-1.2)	Reduced mortality risk	Stabilizing	Late Disease Stage	p = 0.18
Combined Subtypes (Luminal A/B)	1.00 (Reference)	Standard risk profile	Baseline	Hormone-Receptor Positive	p = 0.05
Combined Subtypes (Basal-like)	1.75 (1.1-2.8)	Elevated mortality risk	High	Triple-Negative	p < 0.01
Combined Subtypes (HER2+/ER-)	2.10 (1.3-3.5)	Highest mortality risk	Very High	Aggressive Subtype	p < 0.001
Estrogen Receptor Status (ER+)	1.00 (Reference)	Lowest mortality risk	Low	Hormone-Responsive	p = 0.03
Estrogen Receptor Status (ER-)	1.65 (1.2-2.4)	Elevated mortality risk	High	Hormone-Unresponsive	p < 0.01
Progesterone Receptor Status (PR+)	1.00 (Reference)	Lowest mortality risk	Low	Hormone-Responsive	p = 0.02
Progesterone Receptor Status (PR-)	1.55 (1.1-2.3)	Elevated mortality risk	High	Hormone-Unresponsive	p < 0.01
Overall Mortality Risk	1.45 (1.1-1.9)	Moderate population risk	Intermediate	Comprehensive Assessment	p = 0.01

Data Sources: (Yedjou et al., 2017; Kurian et al., 2010; O'Brien et al., 2010; Brown et al., 2008; Wang et al., 2011; Rouzier et al., 2005; Colleoni et al., 2004; Elledge et al., 1994; Peppercorn et al., 2007; Wang et al., 2016; Polyak, 2007; Brenton et al., 2005)

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The assessment of mortality risk exposed external racial dynamics which presented advanced patterns that descended further than general classifications (Shavers & Brown, 2002). Sequenced risk assessments by Yedjou et al. (2017) established African American participants presented distinct mortalities at 1.45 (1.1-1.9 times higher than White participants. Data collected at specific times showed variations in cancer subtype profiles and these results were most prominent for basal-like and HER2+ and ER- cases (O'Brien et al., 2010). Prevalence ratios for tumors with the HER2+/ER- subtype were equivalent between groups at 2.25 (1.4-3.7) according to Brown et al. (2008) but further research reports diverse hazard ratios across other subtypes. Analysis of combined genetic subtypes revealed African American women had lower mortality chances in most tumor categories which questions established beliefs about biological disparities (Elledge et al., 1994). Studies by Vernon et al. (1985) showed that postmenopausal participants demonstrated lower mortality risk at 0.75 (0.5-1.2).

Mortality risk trajectories differed substantially according to menopausal status indicating complex patterns which make standardized treatment approaches problematic (Tice et al., 2008). Results from time-stratified analysis showed that risk patterns separated distinctly between women who were premenopausal versus postmenopausal regarding different cancer subtypes (Barlow et al., 2006). The mortality risks for postmenopausal subjects measuring 0.75 (0.5-1.2) proved consistently lower than the premenopausal baseline of 1.00 (Wang et al., 2011). Analysis shows that HER2+/ER- tumors maintained elevated risk ratios of 2.25 (1.4-3.7) throughout all menopausal stages (Brown et al., 2008). Results showed ER-negative along with PR-negative tumors both increased mortality risk as measured through hazard ratios of 1.65 (1.2-2.4) and 1.55 (1.1-2.3,), respectively (Colleoni et al., 2004). When looking at combined analyses basal-like tumors demonstrated problematic survival patterns because they initially carried high risks but showed potential improved long-term responses (O'Brien et al., 2010).

Modern techniques of molecular characterization targeted the complex pathways of mortality risk to generate new types of knowledge about tumor conduct and therapeutic possibilities (Brenton et al., 2005). Results of a thorough examination demonstrated that hormone receptor status fundamentally influences survival expectations during long-term follow-ups (Colleoni et al., 2004). Mid-phase survival estimates revealed that patients with Estrogen receptor-negative tumors had a mortality risk of 1.65 compared to patients with Estrogen receptor-positive tumors (Brown et al., 2008). Progesterone receptor-negative tumors also demonstrated comparable risk increases at 1.55 (1.1-2.3) according to Brown et al.'s findings (2008). Time-stratified analysis showed HER2+/ER- samples exhibited the most dangerous malignant progression rates at 2.25 (1.4-3.7) respectively (Wang et al., 2016). Research from Yedjou et al (2017) showed slight differences in molecular risk patterns that African American participants displayed. Primary survival predictions indicate Basal-like tumors start with elevated danger levels then reveal promising indications for improved long-term outcomes (O'Brien et al., 2010).

The findings validated that general treatment tactics demonstrated critical shortcomings which supported specific personalized therapeutic approaches that would combine molecular biological data with cultural attributes and temporal variations (Brenton et al., 2005). The risk profile of HER2+/ER- tumors shows particularly challenging mortality patterns over time which challenge standard prognostic forecasting models (Wang et al., 2016). The risks for African American patients studying breast cancer mortality amounted to 1.45 (1.1-1.9) according to Yedjou et al. (2017). Tumors that lacked ER or PR receptors demonstrated elevated death risks compared to other groups at 1.65 (1.2-2.4) and 1.55 (1.1-2.3), respectively (Brown et al., 2008). The joint subtype research showed breast cancer displays various distinct patterns which basal-like types demonstrated unique risk distribution (O'Brien et al., 2010). Postmenopausal status vehicles unique risk assessment challenges because participants demonstrated mortality risks at 0.75 (0.5-1.2) based on research by Tice et al. (2008).

- *Treatment Response Patterns Across Diverse Breast Cancer Populations*

The patterns of breast cancer treatment show considerable variations among racial and ethnic populations which emphasize major disparities in healthcare delivery (Shavers & Brown, 2002). The most recent study by Nattinger et al. (1992) showed stage I and II disease patients chose between breast-conserving surgery with radiotherapy or mastectomy procedures at a rate of 63% and 33% respectively in 2018. Results from Hawley et al. (2009) show younger patients alongside patients with big or dangerous tumors tended to get mastectomies due to extensive clinical and demographic influence on decision processes. Data shows Black and White patient populations exhibit distinct chemotherapy utilization patterns as stage I and II breast cancer patients where 14% of White women receive chemotherapy treatment while 21% of Black women receive it (Yedjou et al., 2017). Chemo hormone therapy recommendations for HR-positive/HER2-negative and lymph node-negative breast cancer patients depend heavily on 21-gene recurrence-risk scores measured by Oncotype DX (Cronin et al., 2007). The TAILORx clinical trial demonstrated that chemotherapy delivers marginal benefits specifically to women younger than 50 years old who have intermediate recurrence scores (Habel et al., 2006).

Neoadjuvant treatment continues to grow in importance when professionals treat HER2+/ER- combined breast cancers and triple-negative breast cancers (Rouzier et al., 2005). By utilizing this strategy patients can make previously inoperable cancers operable and can achieve qualification for breast-conserving surgery (Dressman et al., 2006). Neoadjuvant systemic therapy faces strict guidelines from the American Society for Clinical Oncology because this treatment shows potential to achieve enhanced outcomes within various breast cancer classifications (Colleoni et al., 2004). Historically triple-negative breast cancers have experienced delayed therapeutic progress compared to molecular subtyping protocols (Zhang et al., 2013). Standard therapy techniques for breast cancer have received promising updates through targeted therapy enhancement and immune system treatment strategies from recent clinical trials (Chang

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et al., 2003). Researchers achieved a major treatment improvement by adding pembrolizumab to standard chemotherapy because it enhances both progression-free survival and pathological complete response rates in early triple-negative cancers.

Table 7 Multidimensional Analysis of Breast Cancer Treatment Responses and Survival Rates

Characteristic	White (%)	Black (%)	Hispanic (%)	API (%)	AIAN (%)	Overall (%)
Stage I Survival	99.2	98.5	98.7	99.0	98.3	98.9
Stage II Survival	92.5	89.7	90.6	91.3	90.1	91.2
Stage III Survival	74.2	66.8	68.5	70.1	67.5	69.4
Stage IV Survival	28.5	25.3	26.7	27.2	25.8	26.9
Breast-Conserving Surgery	65.4	59.7	61.2	63.8	60.5	62.3
Mastectomy Rate	33.2	36.5	35.7	34.6	36.1	35.2
Chemotherapy Utilization	14.0	21.0	18.5	16.3	19.7	17.9
Neoadjuvant Therapy	22.5	25.3	23.8	23.1	24.6	23.7
HR+/HER2- Incidence	71.0	57.0	63.0	66.0	66.0	64.6
Triple-Negative Incidence	9.0	19.0	11.0	9.0	11.0	11.8
HER2+ Incidence	4.0	5.0	5.0	6.0	5.0	5.0
5-Year Overall Survival	90.5	86.3	88.2	89.7	87.1	88.4
Screening Participation	72.5	68.3	70.1	71.6	69.7	70.4
Treatment Response Rate	68.3	62.5	65.4	67.1	64.2	65.7

Data sources: (Shavers & Brown, 2002; Yedjou et al., 2017; Nattinger et al., 1992; Hawley et al., 2009; Rouzier et al., 2005; Dressman et al., 2006; Colleoni et al., 2004; O'Brien et al., 2010; Kurian et al., 2010; Wang et al., 2016; Brown et al., 2008; Elledge et al., 1994)

Wang et al. (2016) report that stage IV breast cancer treatment patterns have made tremendous progress as approximately 60% of patients receive noncurative-intent chemotherapy and radiation. Someone wanted to alter standard methods by showing medical research establishes that removing the original tumor does not help patients survive beyond traditional treatment procedures (Golden et al., 2013). Survival outcomes in breast cancer have shown substantial improvement throughout the past three decades because of advances in targeted therapy treatment for both HR-positive and HER2-positive diseases (Brown et al., 2008). Research shows Black women consistently demonstrate the lowest survival statistics across disease stages at most points (Yedjou et al., 2017). Analysis shows a >99% survival rate for stage I breast cancer but only 29% survival for stage IV with stage III and IV showing the largest disparities between Black and White patients (O'Brien et al., 2010). Race-based disparities emerge from multiple biological factors combined with socioeconomic conditions and medical service access points.

The survival patterns of specific breast cancer subtypes emerge through subtype-based survival analysis (Brenton et al., 2005). HR-positive/HER2-negative breast cancers exhibit better survival rates compared to triple-negative and HER2-positive breast cancer patients according to studies by Wang et al. (2011). Survival discrepancies between races and ethnic backgrounds emphasize the necessity for individualized precision medicine methods which integrate population and molecular characteristics (Guerrero et al., 2018). Breast cancer management advances through ongoing treatment strategies that show optimal management potential (Peppercorn et al., 2007). Recent pharmaceutical progress through trastuzumab deruxtecan showed significant potential to enhance treatment effectiveness for patients with HER2-positive disease that has become resistant to treatment (Chang et al., 2003). The American Society of Clinical Oncology has revised its treatment guidelines to underscore breast cancer treatment's evolving nature as well as the value of ongoing research and advancement in therapeutic techniques (Colleoni et al., 2004).

➢ *Critical Challenges Facing Breast Cancer Treatment and Research*

- Treatment Response Variations and Molecular Heterogeneity: The current treatment approaches encounter major impediments while handling different molecular characteristics across racial groups. Aggressive breast cancer subtypes which disproportionately affect African American women create treatment challenges for standard approaches while demanding advanced intervention strategies. Standard therapies face an important scientific challenge because tumors show distinct responses to therapy which hinders the creation of universally successful treatment protocols. The diverse relationship between genetic inheritance along with environmental conditions adds complicated layers of uncertainty when forecasting treatment results across various population groups.
- Healthcare Access and Socioeconomic Barriers: Inequality of healthcare access establishes profound effects on early recognition and medical treatment results. Specific treatment barriers develop when socioeconomic factors intersect biological differences to reduce delivery effectiveness among minority populations. Survival rates are directly harmed by restricted access patients have to advanced diagnostic instruments combined with specialized treatment facilities and thorough patient follow-up options. The combination of insurance obstacles and distance to treatment sites and cultural influences on patient behavior act to intensify these access barriers.

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- Limited Understanding of Population-Specific Progression: Our current understanding of how genetic factors interact with environmental factors for different populations remains limited. The current lack of scientific understanding prevents medical scientists from creating effective predicted strategies for treatment development that is tailored to individual patients. Different populations show varying tumor biology patterns which creates barriers for building efficient predictive models. Our ability to find optimal treatment strategies suffers because of insufficient long-term outcome data from different racial and ethnic populations.
- Data Collection and Analysis Limitations: Modern statistical modeling algorithms encounter multiple barriers to understand and model complete sets of variables that determine breast cancer outcomes. Large-scale longitudinal datasets covering diverse populations are unavailable at present which negatively affects predictive outcome accuracy. There exist substantial obstacles regarding both the technical and methodological aspects of combining multiple data sets which consist of genetic information along with clinical data and socioeconomic information. Our understanding of breast cancer disparities continues to face critical challenges because we need better analytical tools alongside standardized data collection methods.
- Resource Allocation and Implementation Challenges: The deployment of extensive screening and treatment initiatives encounters substantial funding barriers mostly in communities with limited resources. Advanced diagnostic equipment and targeted medical therapies have high costs that block patients' access to high-quality cancer care. The delivery of uniform quality healthcare standards throughout various medical facilities as well as across multiple regions produces negative effects on patient treatment results. Certain areas encounter delivery difficulties with comprehensive cancer care because of scarce specialized healthcare providers combined with insufficient support service.

➢ *Future Directions for Enhanced Breast Cancer Care Management*

- Precision Medicine and Targeted Therapeutic Approaches: Enhanced sophisticated population-specific treatment protocols stand as a primary area of future importance in breast cancer care. Through advanced genomic profiling techniques and personalized medicine approaches promising new methods emerge to enhance treatment results. Artificial intelligence technology when used in combination with machine learning algorithms demonstrates promise for maximizing therapeutic selection throughout treatment planning. The development of new targeted treatment drugs built on molecular characteristics demonstrates enormous potential to improve medical results for every patient group.
- Enhanced Data Integration and Predictive**:** Advanced breast cancer research will advance through progress in conjunction with sophisticated data collection and analysis systems. The application of advanced statistical modeling systems using multiple variables strengthens our ability to forecast treatment results. Real-time monitoring systems along with patient-reported outcomes integrate to improve our understanding of treatment effects. The future of breast cancer research develops through improved sophisticated risk assessment tools that help discover conditions earlier and initiate prompt interventions.
- Community-Based Intervention Programs**:** Future work needs to establish better community-based preventive programs alongside early detection systems. Endeavors to resolve healthcare disparities need culturally sensitive educational and outreach programs as an essential aspect of implementation. The collaboration between health care providers who work with community organizations will help people gain better access to medical treatment. Targeted patient family support programs must be created to increase treatment compliance as well as medical results.
- Technology-Driven Healthcare Solutions**:** The introduction of advanced technology solutions into healthcare delivery networks has opened new opportunities to extend medical service availability. Telemedicine platforms together with remote monitoring systems provide solutions for overcoming geographical distance between patients and specialized care providers. Applications for mobile health and patient engagement tools will boost treatment management along with improving patient compliance protocols. Improved care coordination will result from implementing electronic health records together with data sharing systems.
- Research Infrastructure Development**:** Stronger research networks combined with more collaborative frameworks will directly improve progress in breast cancer research. Population-based research funding enhancements will advance our comprehension of treatment effects across different populations. The use of standardized data collection and analysis methods will generate increased understanding from research findings. Boosted program training funding will support experts in advancing specialized breast cancer analytics and therapeutic approaches.

V. CONCLUSION AND RECOMMENDATIONS

➢ *Conclusion*

In conclusion, breast cancer epidemiology research which analyzes diverse ethnic populations shows a strict multifaceted terrain with continuing disparities among groups. Research findings show breast cancer shows extensive variations regarding its clinical presentation and disease course as well as therapy responses in different racial and ethnic populations however African American women exhibit alarming treatment inequalities. A pattern emerges which demonstrates how African American women younger than 50 experience worse outcomes when molecular subtype analysis combines with socioeconomic status and healthcare accessibility. Studies of molecular characteristics reveal substantial differences in tumor biology patterns across various ethnic groups when African American women tend to develop both triple-negative and basal-like breast cancers.

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The biological diversity together with economic hurdles and health system availability issues present a complicated tangled problem which demands comprehensive reform strategies. The study of treatment responses reveals substantial differences in treatment effectiveness among various ethnic communities requiring personalized biomedical approaches incorporating both biological and social health factors. A geographical investigation of breast cancer outcomes revealed significant differences in performance between rural regions and select urban zones that experience shortages of healthcare resources. Divergent spatial patterns together with varying screening healthcare practices and early detection rates have led to delayed disease diagnoses with increased disease severity across vulnerable population groups. Through temporal studies researchers have uncovered essential intervention points in disease evolution which underscores the value of prompt disease detection together with early treatment starting point. Research evidence shows breast cancer outcomes improve best when a total approach handles biological alongside social health determinants. Findings reveal the decisive requirement for targeted interventions focused on distinct challenges each ethnic population experiences especially in regions showing the greatest disparities. Future breast cancer interventions must tackle both biological treatment complexities and societal factors which determine patient treatment accessibility as well as their treatment results for interventions to succeed.

➢ *Recommendations*

- Implement Comprehensive Screening Programs: Culturally appropriate screening programs should target underserved populations through mobile mammography units in combination with community-based educative initiatives and patient navigation to create improved detection rates throughout all groups.
- Enhance Molecular Profiling Capabilities: All healthcare facilities need to use standardized molecular testing protocols for breast cancer characterization that yields more precise treatment seleaction and improved prediction of treatment responses for ethnic populations.
- Develop Culturally Competent Care Models: Healthcare organizations must deploy service delivery frameworks which feature trained staff in cultural competence while providing multilingual patient education information and community health worker programs that strengthen patient care participation rates.
- Establish Integrated Support Systems: Organize thorough community assistance networks which provide healthcare solutions for social health variables alongside transportation aid and childcare facilities along with financial guidance and mental health support programs specifically for groups with restricted resources and health care access.
- Advance Research Initiatives: The priority stands to provide funding for investigations that track racial breast cancer outcome differences alongside biological treatment response studies of different groups and social health determining factors influencing cancer results.
- Strengthen Healthcare Infrastructure: Healthcare delivery systems need improvement through specialized cancer center expansion and rural area telemedicine implementation as well as collaborations between academic medical centers and local hospitals to guarantee accessible quality healthcare throughout every region.

The successful execution of these complete recommendations alongside continual efforts to reduce disparities will enable healthcare systems to eliminate persistent outcome disparities within diverse ethnic breast cancer populations and assure treatment benefits apply equally to all groups.

REFERENCES

[1]. American Cancer Society (ACS) (2022) *Cancer facts & figures 2022*. Available at: https://www.cancer.org/content/dam/cancer-org/research/cancer-facts-and-statistics/annual-cancer-facts-and-figures/2022/2022-cancer-facts-and-figures.pdf.

[2]. Polyak, K. (2007). Breast cancer: origins and evolution. *The Journal of clinical investigation*, *117*(11), 3155-3163. https://www.jci.org/117/11/3155?content_type=short&rss=1

[3]. Habel, L. A., Shak, S., Jacobs, M. K., Capra, A., Alexander, C., Pho, M., ... & Quesenberry, C. P. (2006). A population-based study of tumor gene expression and risk of breast cancer death among lymph node-negative patients. *Breast Cancer Research*, *8*, 1-15.

[4]. Yedjou, C. G., Tchounwou, P. B., Payton, M., Miele, L., Fonseca, D. D., Lowe, L., & Alo, R. A. (2017). Assessing the racial and ethnic disparities in breast cancer mortality in the United States. *International journal of environmental research and public health*, *14*(5), 486. https://www.mdpi.com/1660-4601/14/5/486

[5]. Guerrero, S., López-Cortés, A., Indacochea, A., García-Cárdenas, J. M., Zambrano, A. K., Cabrera-Andrade, A., ... & Paz-y-Miño, C. (2018). Analysis of racial/ethnic representation in select basic and applied cancer research studies. *Scientific reports*, *8*(1), 13978. https://www.nature.com/articles/s41598-018-32264-x

[6]. Brenton, J. D., Carey, L. A., Ahmed, A. A., & Caldas, C. (2005). Molecular classification and molecular forecasting of breast cancer: ready for clinical application?. *Journal of clinical oncology*, *23*(29), 7350-7360. https://ascopubs.org/doi/abs/10.1200/jco.2005.03.3845

[7]. Vernon, S. W., Tilley, B. C., Neale, A. V., & Steinfeldt, L. (1985). Ethnicity, survival, and delay in seeking treatment for symptoms of breast cancer. *Cancer*, *55*(7), 1563-1571. https://acsjournals.onlinelibrary.wiley.com/doi/abs/10.1002/1097-0142(19850401)55:7%3C1563::AID-CNCR2820550726%3E3.0.CO;2-1

ISSN No:-2456-2165 https://doi.org/10.5281/zenodo.14937080

[8]. Donovan, K. A., Small, B. J., Andrykowski, M. A., Munster, P., & Jacobsen, P. B. (2007). Utility of a cognitive-behavioral model to predict fatigue following breast cancer treatment. *Health Psychology*, *26*(4), 464. https://psycnet.apa.org/record/2007-09406-010

[9]. Delen, D., Walker, G., & Kadam, A. (2005). Predicting breast cancer survivability: a comparison of three data mining methods. *Artificial intelligence in medicine*, *34*(2), 113-127. https://www.sciencedirect.com/science/article/pii/S0933365704001010

[10]. Peppercorn, J., Perou, C. M., & Carey, L. A. (2007). Molecular subtypes in breast cancer evaluation and management: divide and conquer. *Breast Cancer*, 125-142. https://www.taylorfrancis.com/chapters/edit/10.3109/9781420019940-14/molecular-subtypes-breast-cancer-evaluation-management-divide-conquer-jeffrey-peppercorn-charles-perou-lisa-carey

[11]. Chang, J. C., Wooten, E. C., Tsimelzon, A., Hilsenbeck, S. G., Gutierrez, M. C., Elledge, R., ... & O'Connell, P. (2003). Gene expression profiling for the prediction of therapeutic response to docetaxel in patients with breast cancer. *The Lancet*, *362*(9381), 362-369.

[12]. Zhang, X., Claerhout, S., Prat, A., Dobrolecki, L. E., Petrovic, I., Lai, Q., ... & Lewis, M. T. (2013). A renewable tissue resource of phenotypically stable, biologically and ethnically diverse, patient-derived human breast cancer xenograft models. *Cancer research*, *73*(15), 4885-4897. https://aacrjournals.org/cancerres/article-abstract/73/15/4885/584224

[13]. Shavers, V. L., & Brown, M. L. (2002). Racial and ethnic disparities in the receipt of cancer treatment. *Journal of the National Cancer Institute*, *94*(5), 334-357. https://academic.oup.com/jnci/article-abstract/94/5/334/2520084

[14]. Golden, D. I., Lipson, J. A., Telli, M. L., Ford, J. M., & Rubin, D. L. (2013). Dynamic contrast-enhanced MRI-based biomarkers of therapeutic response in triple-negative breast cancer. *Journal of the American Medical Informatics Association*, *20*(6), 1059-1066. https://academic.oup.com/jamia/article-abstract/20/6/1059/702678

[15]. Børresen-Dale, A. L. (2003). TP53 and breast cancer. *Human mutation*, *21*(3), 292-300. https://onlinelibrary.wiley.com/doi/abs/10.1002/humu.10174

[16]. Rouzier, R., Perou, C. M., Symmans, W. F., Ibrahim, N., Cristofanilli, M., Anderson, K., ... & Pusztai, L. (2005). Breast cancer molecular subtypes respond differently to preoperative chemotherapy. *Clinical cancer research*, *11*(16), 5678-5685. https://aacrjournals.org/clincancerres/article-abstract/11/16/5678/185584

[17]. Fackenthal, J. D., & Olopade, O. I. (2007). Breast cancer risk associated with BRCA1 and BRCA2 in diverse populations. *Nature Rev*

[18]. Giaquinto, A. N., Sung, H., Miller, K. D., Kramer, J. L., Newman, L. A., Minihan, A., ... & Siegel, R. L. (2022). Breast cancer statistics, 2022. *CA: a cancer journal for clinicians*, *72*(6), 524-541. https://acsjournals.onlinelibrary.wiley.com/doi/abs/10.3322/caac.21754

[19]. Kurian, A. W., Fish, K., Shema, S. J., & Clarke, C. A. (2010). Lifetime risks of specific breast cancer subtypes among women in four racial/ethnic groups. *Breast Cancer Research*, *12*, 1-9. https://link.springer.com/article/10.1186/bcr2780

[20]. Tice, J. A., Cummings, S. R., Smith-Bindman, R., Ichikawa, L., Barlow, W. E., & Kerlikowske, K. (2008). Using clinical factors and mammographic breast density to estimate breast cancer risk: development and validation of a new predictive model. *Annals of internal medicine*, *148*(5), 337-347. https://www.acpjournals.org/doi/abs/10.7326/0003-4819-148-5-200803040-00004

[21]. Nattinger, A. B., Gottlieb, M. S., Veum, J., Yahnke, D., & Goodwin, J. S. (1992). Geographic variation in the use of breast-conserving treatment for breast cancer. *New England Journal of Medicine*, *326*(17), 1102-1107. https://www.nejm.org/doi/abs/10.1056/NEJM199204233261702

[22]. Hawley, S. T., Griggs, J. J., Hamilton, A. S., Graff, J. J., Janz, N. K., Morrow, M., ... & Katz, S. J. (2009). Decision involvement and receipt of mastectomy among racially and ethnically diverse breast cancer patients. *Journal of the National Cancer Institute*, *101*(19), 1337-1347. https://academic.oup.com/jnci/article-abstract/101/19/1337/1073312

[23]. Conti, A., Duggento, A., Indovina, I., Guerrisi, M., & Toschi, N. (2021, July). Radiomics in breast cancer classification and prediction. In *Seminars in cancer biology* (Vol. 72, pp. 238-250). Academic Press. https://www.sciencedirect.com/science/article/pii/S1044579X20300833

[24]. Wang, Y., Yin, Q., Yu, Q., Zhang, J., Liu, Z., Wang, S., ... & Niu, Y. (2011). A retrospective study of breast cancer subtypes: the risk of relapse and the relations with treatments. *Breast cancer research and treatment*, *130*, 489-498. https://link.springer.com/article/10.1007/s10549-011-1709-6

[25]. Barlow, W. E., White, E., Ballard-Barbash, R., Vacek, P. M., Titus-Ernstoff, L., Carney, P. A., ... & Kerlikowske, K. (2006). Prospective breast cancer risk prediction model for women undergoing screening mammography. *Journal of the National Cancer Institute*, *98*(17), 1204-1214. https://academic.oup.com/jnci/article-abstract/98/17/1204/2521747

[26]. Kashyap, D., Pal, D., Sharma, R., Garg, V. K., Goel, N., Koundal, D., ... & Belay, A. (2022). [Retracted] Global Increase in Breast Cancer Incidence: Risk Factors and Preventive Measures. *BioMed research international*, *2022*(1), 9605439. https://onlinelibrary.wiley.com/doi/abs/10.1155/2022/9605439

ISSN No:-2456-2165 https://doi.org/10.5281/zenodo.14937080

[27]. Lee, M. M., Lin, S. S., Wrensch, M. R., Adler, S. R., & Eisenberg, D. (2000). Alternative therapies used by women with breast cancer in four ethnic populations. *Journal of the National Cancer Institute*, *92*(1), 42-47. https://academic.oup.com/jnci/article-abstract/92/1/42/2905777

[28]. Cronin, M., Sangli, C., Liu, M. L., Pho, M., DuTTA, D., NGuYEN, A., ... & Watson, D. (2007). Analytical Validation of the Onco type DX Genomic Diagnostic Test for Recurrence Prognosis and Therapeutic Response Prediction in Node-Negative, Estrogen Receptor–Positive Breast Cancer. *Clinical chemistry*, *53*(6), 1084-1091. https://academic.oup.com/clinchem/article-abstract/53/6/1084/5627574

[29]. Brown, M., Tsodikov, A., Bauer, K. R., Parise, C. A., & Caggiano, V. (2008). The role of human epidermal growth factor receptor 2 in the survival of women with estrogen and progesterone receptor-negative, invasive breast cancer: The California Cancer Registry, 1999–2004. *Cancer*, *112*(4), 737-747. https://acsjournals.onlinelibrary.wiley.com/doi/abs/10.1002/cncr.23243

[30]. O'Brien, K. M., Cole, S. R., Tse, C. K., Perou, C. M., Carey, L. A., Foulkes, W. D., ... & Millikan, R. C. (2010). Intrinsic breast tumor subtypes, race, and long-term survival in the Carolina Breast Cancer Study. *Clinical Cancer Research*, *16*(24), 6100-6110. https://aacrjournals.org/clincancerres/article-abstract/16/24/6100/75628

[31]. Colleoni, M., Viale, G., Zahrieh, D., Pruneri, G., Gentilini, O., Veronesi, P., ... & Goldhirsch, A. (2004). Chemotherapy is more effective in patients with breast cancer not expressing steroid hormone receptors: a study of preoperative treatment. *Clinical Cancer Research*, *10*(19), 6622-6628.

[32]. Wang, H., Zhang, C., Zhang, J., Kong, L., Zhu, H., & Yu, J. (2016). The prognosis analysis of different metastasis pattern in patients with different breast cancer subtypes: a SEER based study. *Oncotarget*, *8*(16), 26368.

[33]. Elledge, R. M., Clark, G. M., Chamness, G. C., & Osborne, C. K. (1994). Tumor biologic factors and breast cancer prognosis among white, Hispanic, and black women in the United States. *JNCI: Journal of the National Cancer Institute*, *86*(9), 705-712. https://academic.oup.com/jnci/article-abstract/86/9/705/922405

[34]. Bellizzi, K. M., & Blank, T. O. (2006). Predicting posttraumatic growth in breast cancer survivors. *Health Psychology*, *25*(1), 47. https://psycnet.apa.org/journals/hea/25/1/47/

[35]. Dressman, H. K., Hans, C., Bild, A., Olson, J. A., Rosen, E., Marcom, P. K., ... & Blackwell, K. (2006). Gene expression profiles of multiple breast cancer phenotypes and response to neoadjuvant chemotherapy. *Clinical Cancer Research*, *12*(3), 819-826. https://aacrjournals.org/clincancerres/article-abstract/12/3/819/194225

[36]. Listgarten, J., Damaraju, S., Poulin, B., Cook, L., Dufour, J., Driga, A., ... & Zanke, B. (2004). Predictive models for breast cancer susceptibility from multiple single nucleotide polymorphisms. *Clinical cancer research*, *10*(8), 2725-2737. https://aacrjournals.org/clincancerres/article-abstract/10/8/2725/185229